A COMPUTER MODEL FOR DETERMINING OPERATIONAL CENTERS OF GRAVITY

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the US Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

A COMPUTER MODEL FOR DETERMINING OPERATIONAL CENTERS OF GRAVITY, by MAJ James J. Donlon, 234 pages.

This thesis examines the applicability of leading artificial intelligence (AI) technology to the determination of operational centers of gravity. Specifically, a modeling technique used in learning agent development is applied. The application of AI to this class of problems is presented, and the considerations for applying AI to operational center-of-gravity determination are discerned from doctrine and scholarly works. Those considerations are then used to develop a general procedure that is suitable for agent development. Analysis of two historical scenarios, The US invasion of Okinawa (1945) and Operation Just Cause in Panama (1989) provide the motivating examples for the modeling. Evaluation of results consists of an analysis of the general applicability of the model for the purpose of agent development and independent expert evaluation of the results obtained from the model applied to the historical scenarios. The result is a model that is suitable as a basis for agent development and which produces results acceptable to subject-matter experts. Recommendations for continued work, agent development, and related research are also presented. Application of this work could lead to the implementation of intelligent decision support to this and related tasks.

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INTRODUCTION

> The information technologies being adopted and the doctrine and tactics they afford will launch another revolution in military affairs. The digitization of the US Army represents the greatest change in warfighting since the Napoleonic era and lays the foundation for the conduct of warfare in the 21st century.
>
> *Army* Magazine

As the quote from *Army* Magazine above testifies (Steele 2001, 19), technological change is bringing about a revolution in military affairs. The Army's recent update to operational doctrine reflects this. The recently published Field Manual 3-0, *Operations* (June 2001), presents information and technology as two of the six dimensions of the modern operational environment (p. 1-8), and adds information as an element of combat power (p. 3-4). This evolution in doctrine recognizes the increased role that information technology is having and will continue to have in military operations. The military has exploited advanced technology in a wide range of applications, including sensor technology, weapons guidance systems, and advanced communications systems. Digitization, a part of the Army's modernization plan for the future force, will increase this advantage by developing and networking a variety of systems designed to aid in decision making, execution, and command and control (Steele 2001, 21).

Problem Statement

Computer-based systems are bringing radical changes to the way the Army plans and conducts operations. As these systems mature, they will eventually perform beyond the automation of well-defined tasks and assist the commander in making sophisticated

military judgments typically reserved for human judgment. While an explosive growth in technology has begotten a wide range of military applications, technology that emulates this level of human reasoning is generally beyond the capabilities of contemporary computer systems and has been strictly a research and development issue. Such "intelligent" applications are in the realm of artificial intelligence (AI). Current research in AI is making significant progress toward the development of systems that perform well on problems previously regarded as too sophisticated for computers to solve alone. An example of such a problem is center-of-gravity determination.

Thesis Question

This thesis examines the applicability of leading AI technology to center-of-gravity determination. Specifically, it addresses the question, Can computers be taught to conduct center-of-gravity determination using current learning agent technology? This represents a first attempt to design computer-based assistance to the determination of centers of gravity. Successful identification of the procedures and considerations necessary to build such an agent could lead to the implementation of an intelligent decision support system to aid in such determinations.

In order to address this central question, it is necessary to answer a number of secondary questions. To begin with, a computer-based decision support system for center-of-gravity determination must have a computer-understandable representation of a usable procedure for the task. Can a problem-solving method for center-of-gravity determination be formalized for use by a computer-based agent? Several subordinate questions follow from this. What are the relevant concepts that need to be in a

computer's knowledge base in order to conduct center-of-gravity determination? Are there generally applicable procedures for center-of-gravity determination? Can center-of-gravity determination procedures be modeled for use by a computer-based agent?

This thesis presents problem-solving modeling needed to develop computer-based agents for center-of-gravity determination. A secondary question pertains to the applicability of that modeling: Will the modeling apply to multiple scenarios? A tertiary question scopes this within the thesis limitations: Will the modeling apply to chosen historical scenarios? Further refining the application to historical scenarios, Can the modeling apply to a scenario that involves a state versus state conflict; and Can modeling performed for one state versus state scenario apply to a second scenario that involves a state versus state conflict?

A third secondary question addresses the validity of the results obtained by this research: Will the modeling produce credible results? This work will present and evaluate a logic for center-of-gravity determination. Two tertiary questions judge whether this approach is appropriate: Does the modeling lead to centers of gravity for selected case studies that are consistent with the choices of experts, and Does the logic of the modeling appear to represent valid reasoning about centers of gravity?

Significance of the Study

This thesis is important to both the technical state of the art in learning agent development and to the doctrinal discourse on center of gravity. In the technical sense, this thesis will help identify the strengths and shortcomings of emerging agent technology by applying it to this complex and contentious problem. Successful identification of the

procedures and considerations for center-of-gravity determination could lead to the implementation of an intelligent decision support system to aid in such determinations. This research directly contributes to the Defense Advanced Research Projects Agency (DARPA) sponsored research in knowledge-based systems and to agent development being conducted by George Mason University (GMU) in conjunction with the United States Army War College (USAWC). It is the aim of that research effort to construct learning agents for center-of-gravity determination. This study provides domain modeling for that agent development.

Beyond the immediate impact, it also contributes to the state of the art in intelligent decision support by demonstrating the applicability of intelligent support to problems beyond the capabilities of current computer systems and typically regarded as "black art." This will encourage further development of systems to aid in strategic and operational decision making, as well as other sophisticated reasoning tasks.

In addition to the technical contribution, there is also a potential doctrinal contribution. This thesis addresses center of gravity because it is a highly conceptual and subjective topic--commonly regarded as an art rather than a science. It has been a subject of study and debate since Carl von Clausewitz first coined the term as a military concept in 1832. This presents a tremendous challenge to the implementation of computer-based systems and even contemporary AI approaches. This provides a worthy domain for developing intelligent systems, as well as the opportunity to contribute to military thinking about the center of gravity. The identification of procedures for computer-based center-of-gravity determination will necessitate a rigorous examination of the current understanding and application of the concept and has great potential to contribute a

practicable methodology and a systematic analysis of key considerations in the process. The agent-building process and indeed, the agents themselves might eventually lead to a more thorough understanding of the concept and its significance.

Background

Artificial Intelligence

AI is a multidisciplinary field that seeks to apply computer-based solutions to problems that are typically regarded as requiring human-level understanding and problem-solving ability. The current state of the art in AI enables scientists to solve a wide range of complex problems using techniques that mimic or are inspired by human behavior and cognition. Such AI applications are normally embedded technologies in overall systems, rather than stand-alone systems in themselves. For this reason, it is easy to overlook the AI contributions in currently deployed military applications, such as targeting systems (e.g., advanced scheduling algorithms), weapons guidance systems (e.g., neural networks), and sensor data interpretation (e.g., probabilistic reasoning). Such technologies contribute a wide range of advanced problem-solving capability in many military systems.

Since its inception, the field of AI has generated a variety of motivations and research approaches. For example, some researchers explore human cognition through computational models, while others solve difficult computational problems by drawing from theories of human intelligence. This has made the definition of the field somewhat tricky. In their textbook, *Artificial Intelligence: A Modern Approach*, Stuart Russell and Peter Norvig provide an excellent framework for defining the field while accounting for

the various means and ends found in AI today (1995, 4-8). They point out that the definitions vary depending on whether the approach to AI is about how humans and machines think or how they act and on whether the goal in either case is to model human behavior or to achieve an ideal standard of rationality. Using this definitional framework, Russell and Norvig describe four broad categories of AI approaches: *acting humanly*, *thinking humanly*, *thinking rationally*, and *acting rationally*. The latter, a “rational agent” approach, is a pragmatic approach to AI that best describes the development of AI-based decision support. In this approach, an *agent* (in AI, something that perceives and acts) is rational to the extent that it does the right thing in pursuit of its goals. Thus many attributes that are central to other AI approaches (e.g., correctness of inference, rigor of logic, humanness of behavior or thought) are emphasized only for the sake of achieving timely, useful analysis. When implemented on computers, rational agents are often referred to as *intelligent agents.* Intelligent agents are discussed in detail in the following section.

While the ultimate aim of AI is to develop systems that exhibit humanlike performance, most current AI applications address problems that have quantifiable descriptions and that require little in the way of humanlike problem-solving knowledge and behavior. AI has solved many complex problems because those problems can be succinctly and accurately described without reliance on a great deal of humanlike knowledge or reasoning. In contrast, more sophisticated applications usually rely on the encoding of more humanlike reasoning in a form suitable for computer-based storage, retrieval, and reasoning.

Intelligent Agents

In general, an intelligent agent is a system that perceives, reasons, and acts in pursuit of its goals (Russell and Norvig 1995, 31-49). It perceives inputs from its environment through sensors of some sort. The environment may be the physical world, inputs from a user via a graphical user interface, signals from other agents, the Internet, or any other complex environment. It reasons to interpret those perceptions, to draw useful inferences, to solve problems, and to plan its actions. It acts upon the environment to accomplish the goals or tasks for which it was designed (Tecuci 1998, 1-3). In this sense, humans are agents of the most-sophisticated sort. At the least-sophisticated level, a thermostat can be described as a simple reflex agent, in that it perceives the temperature of its environment and affects the functioning of heating and air conditioning to achieve the desired room temperature. The sort of agent under consideration for this thesis falls between these levels of sophistication. A center-of-gravity agent should perceive inputs regarding the relevant circumstances of a military scenario, conduct reasoning to determine sensible centers of gravity for that scenario, and explain them to a user.

The following characteristics of intelligent agents (Tecuci 2001) provide a useful framework for describing an agent for center-of-gravity determination.

Knowledge Representation and Reasoning

It is typical to describe the relevant aspects of the agent's environment as the agent's application *domain*. In order to function, an intelligent agent must possess an internal representation of the external application domain. A *representation* is a formal encoding of the relevant aspects of that domain--things that exist in the environment and

the relationships between them. These aspects are represented by symbolic expressions that a computer can store and manipulate during reasoning. The correspondence between the concepts in the environment and the representation of those concepts in the agent allows the agent to reason by combining rules for logical inference, the domain model, and observations from the environment.

The component that implements reasoning is referred to as the problem-solving engine. This is a general problem-solving mechanism that manipulates the data structures in the knowledge base to reason about the input problem, to solve it, and to determine the actions to perform next. In this way, the problem-solving engine is a reusable, general-purpose reasoning mechanism, suitable for use in a wide variety of application domains. By maintaining this separation between knowledge representation and reasoning mechanism, agent developers can develop general-purpose agent shells that can be reused by simply encoding the knowledge for a new application domain.

Transparency and Explanation

Transparency means that an agent's reasoning is open to inspection by a user. If the knowledge and reasoning steps used by the agent are accessible and understandable to humans, then the results will be easier to use and adjust. An agent is capable of explanation to the extent that it can present not only its conclusions, but also an appropriate justification based on its reasoning. This enhances the acceptability of even correct agent conclusions. In contrast, users may justifiably distrust results from a "black box" agent that cannot explain its reasoning.

Ability to Communicate

An agent should be able to communicate with its users or other agents. Depending on its intended use, this communication may be extensive or limited, and may rely more or less on natural languages, such as English. Some agents, for example, accept inputs from users via graphical user interface interactions and communicate outputs via graphical displays and limited natural language. Others may process inputs and outputs using a wider range of natural language expressions. Whatever the communication language or modality, it should be as natural to the human users as possible, but be sufficiently unambiguous to enable the agent to accomplish its task. While natural language is an ideal communications modality for the human user, computers are incapable of unrestricted natural language understanding and generation due to the complexity of human communication. Natural language processing is a challenge in agent design, as human experts best communicate their expertise in plain language, not in ways understandable to the computer; and computers are not inherently capable of effective communication with humans. A tractable compromise is to constrain human-agent communications to a limited subset of natural language and mediate its use through a controlled interface.

Use of Huge Amounts of Knowledge

In order to solve difficult problems, an intelligent agent must rely on a huge amount of domain knowledge in a repository called a *knowledge base*. The knowledge base contains representations (as discussed earlier) that correspond to the relevant concepts in the environment, as well as information about the user and the goals he wants

to achieve. Systems that rely on knowledge bases are called *knowledge-based systems*. They traditionally require the work of a *knowledge engineer* to analyze the domain, formalize concepts and problem-solving methods, and program the computer accordingly. Because this is difficult and costly to do, sophisticated knowledge-based systems are often impractical to implement. This "knowledge acquisition bottleneck" is a key obstacle to the development of knowledge-based AI systems for domains such as center-of-gravity determination.

In addition, completed knowledge-based systems often require significant maintenance to the knowledge base to remain competent in changing environments. This maintenance cost is usually much higher than the cost of the initial development. In addition, the subject-matter experts that were used in the development phase of agent implementation are often not available to the knowledge engineers during maintenance. This "knowledge maintenance bottleneck" is another significant obstacle to agent construction and contributes to the obsolescence of existing agents.

Use of Heuristics

Intelligent agents are often implemented for problems that lack efficient computable solutions. An effective technique to solve such complex problems involves the use of heuristics. A heuristic is a rule of thumb, strategy, trick, simplification, or similar device that drastically limits the search for solutions in large problem spaces or reduces the amount of knowledge needed to reason about the problem. Heuristics usually sacrifice optimality for practicality, often enabling solutions that are "good enough" for the task at hand and achievable in a timely manner. Agents make the best use of

heuristics in domains that require the modeling of human judgment, rather than precise computations.

Reasoning With Incomplete or Conflicting Data

Because an agent rarely has a perfect understanding of the environment, it must be designed to proceed with problem solving when data is incomplete or contradictory. Depending on the agent's design, it can make assumptions to fill in for missing facts, draw from historical cases, or seek guidance from a human user. Designing this default reasoning and contradiction handling is often a challenging aspect of agent design.

Ability to learn and adapt

Many agents are designed to learn as a result of interactions with their environment. This allows the agent to improve its competence (i.e., ability to solve a broader class of problem and to make fewer mistakes in problem solving) and efficiency (i.e., the economical use of time or space resources). In some agents, learning is an integral part of the development methodology, as the agent acquires knowledge primarily by interacting with and learning from its environment. An intelligent agent that learns as a result of interaction with its environment can be called a *learning agent*.

Benefits of Intelligent Agents

When development challenges are managed and overcome, agents can provide significant support to complex reasoning tasks, such as center of gravity analysis. Intelligent agents can capture the best human expertise in a domain and make that

expertise available in a range of applications. A center-of-gravity agent, for example, might be put to use in military education to educate officers in the concept and its application, as well as to assist in strategic and operational planning.

An intelligent agent and human user can complement each other's capabilities in significant ways. While a human expert can provide new analysis to help teach an agent, the agent can consistently and thoroughly apply all of what has previously been learned. A human can provide creativity or unique experience to augment an agent's analysis. An agent can quickly access a practically unlimited repository of previous cases for similarities and conclusions, unconstrained by the limits of fatigue, stress, bias or memory loss, filling the role of a thorough and dispassionate assistant. Rather than replacing humans, intelligent agent technology makes it possible for humans and computers to engage in mixed initiative problem solving that takes advantage of the strengths of each. As information technology continues to evolve, users can expect an increase in this kind of human-computer collaboration in future systems.

The Disciple Learning Agent Methodology

Recent AI research has investigated the application of AI to military course of action analysis and strategic crisis management (Cohen et al. 1998). This research relies heavily on humanlike reasoning with a significant amount of domain knowledge and emphasizes the development of technologies for knowledge acquisition, knowledge base management, and problem solving. This research has resulted in improved knowledge-based reasoning and agent technologies that exploit humanlike problem-solving ability.

A highly successful technology in this research, the Disciple learning agent (Tecuci 1998), demonstrated that highly effective knowledge-based agents could be developed via direct interaction with domain experts to solve these knowledge-intensive problems. This agent technology recently proved effective in critiquing military courses of action (Tecuci et al. 2001). The course of action agent was developed to address a knowledge-based reasoning challenge problem in the DARPA High Performance Knowledge Bases (HPKB) research program. The specific problem addressed by the Disciple agent was to identify the strengths and weaknesses of a military course of action with respect to the principles of war and the tenets of army operations. This was the most difficult of a range of course of action critiquing tasks addressed by the HPKB component technologies. Despite the fact that the tasks solved by the Disciple agent involved highly subjective humanlike reasoning, the technology performed the best of all competing technologies by all measures of evaluation (Tecuci et al. 2001).

To perform course of action critiquing, the agent took as input a description of a course of action statement and sketch describing the plan. (The sketch and statement inputs were provided through another HPKB component, which interpreted both the sketch and statement in machine-readable terms before passing them to problem solvers such as Disciple). The Disciple course of action critiquing agent successfully provided accurate and pertinent answers pertaining to each principle of war and each tenet. The agent reproduced all of the model answers expected in the evaluation, and identified a number of valid novel answers as well. For example, in response to the question, To what extent does this course of action conform to the principle of mass, the agent produced the following answer regarding the example given:

> There is a major strength in COA411 with respect to mass because BLUE-TASK-FORCE1 is the MAIN-EFFORT1 and it acts on the decisive point of the COA (RED-MECH-COMPANY4) with a force ratio of 10.6, which exceeds a recommended force ratio of 3.0. Additionally, the main effort is assisted by supporting action SUPPRESS-MILITARY-TASK1 which also acts on the decisive point. This is good evidence of the allocation of significantly more than minimum combat power required at the decisive point and is indicative of the proper application of the principle of mass. (Tecuci et al. 2001)

In response to a similar question about the principle of objective for the same example, the agent produced this answer:

> There is a weakness in COA BLUE-BRIGADE-COA4-2-1-MT with respect to objective because BLUE-TASK-FORCE1 is the MAIN-EFFORT1 of the COA and its assigned action is of a different type and has a significantly different focus than the main action of the COA BLUE-BRIGADE-TASK. The main effort is meant to accomplish the purpose of the COA and this may not be supported by the main effort having a different type of task and objective than the COA. (Tecuci et al. 2001)

These results are completely machine-generated critiques of a military course of action. The detail and reasoning that is evident in these two examples illustrates the agent's capabilities and its potential for application to center of gravity.

Following on the success of the course of action application, efforts are now under way between GMU and USAWC to apply Disciple to center-of-gravity determination. The first year's work has so far demonstrated that Disciple is capable of identifying *candidate* centers of gravity at the *strategic* level. This thesis contributes new modeling and domain analysis that can be used in future agent development to select centers of gravity at the operational level.

The Disciple agent development software and methodology were developed at the Learning Agents Laboratory at GMU. A Disciple agent effectively learns problem-solving knowledge and procedures as a result of teacher-student style interaction with

subject-matter experts. Because the agent is taught directly by a subject-matter expert, a knowledge engineer is not directly involved in this development, and therefore the aforementioned knowledge acquisition bottleneck is largely avoided. In addition the agent is developed by domain experts themselves for their own use or for use by other similar users. Disciple continues to learn concepts as a result of this teacher-student interaction, resulting in the continual refinement of agent competence and efficiency through the life of the application. Since the agent learns from continued interactions with users, Disciple also overcomes the knowledge maintenance bottleneck.

To aid in human-computer interaction, Disciple accepts natural language descriptions from the user. Disciple uses these plain language expressions for maintaining its representation of the application domain. This later enables the agent to construct articulate and understandable explanations of its reasoning by recombining those expressions. Consequently, Disciple agents can be developed more rapidly and maintained more easily than with other contemporary AI approaches (Tecuci et al. 2001).

The Disciple agent development methodology (Tecuci 1998) is the technical basis for this research. The concepts and procedures formalized to test the research questions in this thesis were developed based on Disciple's knowledge base and problem-solving methodology. Faculty at the USAWC and the Command and General Staff College (CGSC) provided feedback on the validity of the modeling. Chapter 3 presents this methodology in detail.

Limitations and Delimitations

There is a large body of literature on the center of gravity, representing a variety of definitions and applications of the topic. Although much work has been done to reconcile these differences, contentious issues remain. Thus an important limitation of this study is that it cannot simultaneously account for all views of center of gravity. In addition, this thesis does not attempt to resolve contentious issues regarding center-of-gravity definition and determination.

This thesis only addresses center-of-gravity determination at the operational level. In the interest of scope, it does not directly deal with the strategic level other than to acknowledge current related work at that level. Tactical centers of gravity are not addressed at all in this thesis.

In addition, this thesis addresses only conventional warfare in state versus state conflict. Motivating examples are a necessary as a basis for the work. While many potential sources of examples exist, this thesis draws from selected official campaign histories provided by the USAWC, for which a center of gravity analysis has been done at the operational and strategic levels. This provides several important advantages, in that these scenarios provide a credible starting point for analysis, the benefit of historical hindsight, a "gold standard" for judging the acceptability of an agent's analysis, and a body of qualified experts familiar with the scenarios (i.e., USAWC faculty) who are willing to contribute to this effort. From this body of historical scenarios, this thesis analyzes examples of conventional state versus state conflict. This thesis does not attempt to address other types of operations and scenarios.

This thesis draws from the Disciple methodology of agent development as the technical basis for testing the research questions and does not consider other agent development methodologies. Furthermore, AI techniques other than intelligent agents are not considered.

Assumptions

Several assumptions relate to the various interpretations and definitions of the center of gravity. One is that the joint and Army doctrinal definitions are essentially consistent and are a sufficient basis for this study. Another assumption is that the conclusion regarding the applicability of the selected agent development methodology to center-of-gravity determination is not sensitive to the definition being tested. That is, if the methodology can be applied to successfully model one approach to center-of-gravity determination, it will also likely succeed for other approaches to center-of-gravity determination. Because an instructable agent learns the preferences of the teacher, it can adapt to a wide range of preferences within the domain. A review of the literature (chapter 2) examines in greater detail the definition of center of gravity and the application of intelligent agents.

Summary

This chapter has proposed that AI technology, specifically the Disciple learning agent methodology, is applicable to assist in center-of-gravity determination. Specifically, this thesis addresses the question, Can computers be taught to conduct center-of-gravity determination using current learning agent technology? If successful,

such an application would help advance the state of the art in intelligent agent research. It would also contribute to the military application of center of gravity including educating officers and providing assistance to strategic and operational planning.

The next chapter, “Literature Review,” surveys the doctrinal and scholarly work in both AI and center of gravity. Chapter 3, “Research Methodology,” presents the procedures that were used to develop and test the modeling needed by a center-of-gravity agent, and thus answer the research question. Chapter 4, “Analysis,” presents the results of modeling and evaluation. Finally chapter 5, “Conclusion and Recommendations,” reviews the answers to the research questions posed in the thesis, makes recommendations for the application of the research, and suggests directions for further research.

CHAPTER 2

LITERATURE REVIEW

Introduction

In addressing the primary research question, Can computers be taught to conduct center-of-gravity determination using current learning agent technology, this thesis draws from both research techniques in AI and current doctrine and scholarly literature on center of gravity. Therefore, this chapter reviews both areas. The chapter begins with an examination of the current state of the art in the relevant areas of AI. It then presents the extant scholarly literature and current doctrinal sources for center-of-gravity definition and application.

Works in Artificial Intelligence

AI is a relatively young field of study. The term was coined in 1956 by John McCarthy at a workshop that unified a number of emerging efforts to relate automata and human intelligence. The overarching interest of this group was the proposition that machines could be made to think in ways similar to the ways that humans think. The classic benchmark for this endeavor was adopted from earlier work by mathematician Alan Turing, who proposed what has come to be known as the Turing Test (Turing 1950). Essentially, this test consists of a person blindly questioning both another person and a computer. If, as a result of the exchange, the questioner is unable to distinguish between the other person and the computer, then the computer can be described as "intelligent." In the one-half century since its inception, the Turing Test has endured in a variety of forms as a central goal of AI (Gregory and Zangwill 1998). While researchers

have yet to design a system capable of passing a rigorous Turing Test, significant advances have been made in a number of AI subfields, and research in AI remains very active. Extensive histories of AI can be found on the World Wide Web, courtesy of the American Association of Artificial Intelligence (AAAI) (AAAI 2001).

There is a great deal of literature available regarding the current state of AI. For the beginner, the student text *Artificial Intelligence: An Executive Overview* (USMA 1994) is still useful for surveying the field in mostly nontechnical terms. Although the text is no longer updated, copies can still be obtained from the academy. Alternatively, copies can be requested from the Knowledge Engineering Group at the USAWC, where this text is used as a source of readings in an executive-level overview of AI.

Already cited in the introduction, the text by Russell and Norvig (1995) is today's definitive technical introduction to AI. Other popular current texts include George Luger's *Artificial Intelligence: Structures and Strategies for Complex Problem Solving* (2001) and Nils J. Nilsson's *Artificial Intelligence: A New Synthesis* (1998).

Several classic works have had a lasting influence on the field, and yet are accessible to the casual reader. One of these is Marvin Minsky's *The Society of Mind* (1986), which presents a series of nontechnical essays on the nature of the human mind, consciousness, and intelligence. Ray Kurzweil was highly influential with *The Age of Intelligent Machines* (1990) and more recently, with *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999). Both of these works present provocative, readable glimpses into the future of AI.

Professional associations are excellent sources for the latest developments in the field. AAAI hosts a variety of conferences in all AI fields of study and publishes the

association's journal, *AI Magazine*. The Institute of Electrical and Electronics Engineers (IEEE) Computer Society, another major domestic professional society, publishes the widely read *IEEE Intelligent Systems*.

The Disciple approach to agent design is well documented. *Building Intelligent Agents*, by Gheorghe Tecuci, presents an overview of this methodology and architecture for the construction of learning agents (1998). It is also an excellent introduction to agent design in general. More recently, a number of journal articles and conference papers provide more updated technical details and applications of this research. Of particular interest is the article "An Innovative Application from the DARPA Knowledge Bases Programs: Rapid Development of a Course of Action Critiquer," from *AI Magazine* (Tecuci et al. 2001). This article describes the application of Disciple to the task of critiquing military courses of action as described in chapter 1. Disciple's performance on this highly subjective and challenging task was the primary inspiration for the application of Disciple to center-of-gravity determination.

Some preliminary work has been done specifically on the application of AI to center-of-gravity determination. In 1995, researchers at USAWC applied knowledge engineering techniques to discern a formal method for the determination of centers of gravity. The resulting literature is a 1995 Command and General Staff College Master of Military Arts and Sciences thesis by Timothy Keppler, entitled "The Center of Gravity Concept: A Knowledge Engineering Approach to Improved Understanding and Application." While this work did not lead to the sort of formalization that this thesis proposes, it provides a detailed discussion of the considerations used in human reasoning for strategic centers of gravity.

Keppler's thesis was followed by the 1996 USAWC monograph by Phillip Kevin Giles and Thomas P. Galvin, "Center-of-gravity determination, Analysis, and Application," which presents essentially the same work. Giles and Galvin provide a guide for the application of this formal method for conducting center of gravity analysis at the strategic and operational levels. The monograph is accompanied by a flowchart that guides the determination. In preparing the model, the authors consulted numerous sources of opinion on the topic, to include doctrine, extant scholarly works, and interviews with subject-matter experts at USAWC. This work provides very useful material for agent development because it presents a systematic and substantiated view of the considerations for strategic center of gravity analysis and offers a guide for the judgment of human experts. This thesis complements the formalization in that work by attempting to formalize in greater detail the knowledge that human experts bring to bear when analyzing centers of gravity, specifically at the operational level.

The first attempt to apply the existing models to build a computer-based agent for center-of-gravity determination is currently underway at the USAWC. In 2000, the USAWC established a new research project, combining their efforts with those of the Learning Agents Laboratory at GMU, under the direction of the DARPA Rapid Knowledge Formation program (USAWC 2001a). This joint research is investigating the applicability of the Disciple methodology to center-of-gravity determination by applying the USAWC process (Keppler 1995; Giles and Galvin 1996). The goal of the project is to apply and extend the knowledge engineering conducted by Keppler, Giles, and Galvin to develop computer-based agents that can learn center-of-gravity determination directly from subject-matter experts and apply that knowledge for autonomous problem solving.

Potential applications include automated decision support and intelligent assistants for education at the USAWC (Bowman, Lopez, and Tecuci 2001; USAWC 2001a).

The results of the first year of this research show that students at the USAWC were able to construct working agents with very limited assistance from a knowledge engineer and that overall these domain experts found the Disciple methodology appropriate and practicable (Boicu et al. 2001). It is also apparent that the Disciple approach is applicable to the problem. The USAWC monograph "Center of Gravity Analysis: Preparing for Intelligent Agents," by Lieutenant Colonel Michael Bowman, demonstrates that the Disciple methodology can be successfully applied to the determination of candidate centers of gravity at the strategic level (2001). Bowman describes the formalization of knowledge and methods for determining potential centers of gravity for several historical scenarios. In addition, two recent journal articles present the integration of this work into electives and experiments at the college (Bowman et.al. 2001a; Bowman et.al. 2001b).

This effort is in its second year and needs further analysis of the required knowledge for agent development. The USAWC-GMU collaboration has not yet addressed operational centers of gravity and their considerations. It has also not yet addressed the analysis of and selection from the candidates identified. This thesis contributes to that work by modeling operational center of gravity analysis and, for the first time, determining a formal method for selecting from among candidate centers of gravity.

Works in Center of Gravity

In order to apply AI to center of gravity, the significant sources of the concept's definition and application also must be reviewed. First introduced by Carl von Clausewitz in 1832, the concept remains a topic of professional discussion and debate. In his classic *On War*, Clausewitz defines the center of gravity as the dominant characteristic of a force, the "hub of all power and movement, upon which everything depends . . . the point against which all our energies should be directed" (pp. 595-6). He introduced this concept in Book 8 as fundamental to the strategist's problem of determining and defeating enemy strength. Clausewitz advocated attacking these directly when possible, indirectly if necessary. He emphasized primarily that "centers of gravity will be found wherever the forces are most concentrated" (p. 486) and that "the defeat and destruction of his fighting force remains the best way to begin" (p. 596). Today, Clausewitz is still regarded as the primary source of definition of center of gravity. *On War* is the de facto point of departure for any credible debate or discussion.

Doctrinal Basis

Army doctrine today restates the essence of the concept introduced by Clausewitz in the nineteenth century. This concept is presented in consideration of the changed nature of warfare since Napoleon, however. Doctrine provides for its application in conjunction with related concepts (e.g., decisive point). While the concept is essentially the same primary source of strength that Clausewitz described, modern application recognizes that the best way to defeat it is often not through direct attack. Related concepts are further discussed in a later section.

FM 3-0, *Operations*, considers the center of gravity a critical element of operational battle command and a necessary element of operational design (p. 5-6). FM 3-0 defines center of gravity as “those characteristics, capabilities, or localities from which a military force derives its freedom of action, physical strength, or will to fight.” It further asserts, “Destruction or neutralization of the enemy center of gravity is the most direct path to victory…once identified, it becomes the focus of the commander’s intent and operational design” (p. 5-7). This establishes the importance of center of gravity in the current Army operational doctrine and provides a current and authoritative Army definition of the concept.

FM 3-0 also brought the Army definition in line with the definition in joint doctrine at that time. Joint Publication (JP) 3-0, *Doctrine for Joint Operations*, updated three months later, slightly modified the definition of center of gravity to “those characteristics, capabilities, or *sources of power* [emphasis mine] from which a military force derives its freedom of action, physical strength, or will to fight” (p. III-22). Notice that the joint definition of September 2001 differs from the Army definition of June 2001 only in that the more recent and authoritative joint definition substitutes “sources of power” as types of center of gravity where the older definition specified “localities.” This may be an attempt to more clearly distinguish center of gravity from decisive point and discourage the selection of localities as means in themselves that can represent centers of gravity. JP 3-0 stresses the destruction or neutralization of the enemy’s center of gravity as the most direct path to victory (p. III-22). In addition, it specifies the identification of strategic and operational centers of gravity as a fundamental of campaign planning (p. III-8). Joint Pub 1, *Joint Warfare of the Armed Forces of the United States*,

echoes this definition and emphasizes that "finding and attacking enemy COGs [centers of gravity] is a singularly important concept" (p. III-13). JP 1 stresses the practical use of centers of gravity in operational art, stating, "A central consideration in applying the operational art is the location and nature of adversary centers of gravity . . . Accurate identification of these COGs [centers of gravity] will assist in overall campaign planning" (p. V-3).

Several studies have highlighted differences in the way the other armed services define and apply the concept, including Keppler (1995) and the aforementioned USAWC center of gravity monograph (Giles and Galvin 1996). Since the time of that study, the unifying influence of joint doctrine is reflected in the updated and basically consistent service definitions of the center of gravity. Air Force Doctrine Document (AFDD) 1, *Basic Air Force Doctrine*, defines the concept identically to joint and Army doctrine (p. 79). In addition, AFDD 1 states, "The ability to integrate a force quickly and to strike directly at an adversary's strategic or operational center of gravity (COG) is a key theme of air and space power's maneuver advantage" (p. 17). Navy Doctrine Publication (NDP) 1 differs in that it emphasizes the existence of only one center of gravity, "That characteristic, capability, or location from which friendly and enemy forces derive their freedom of action, physical strength, or will to fight," (p. 72). "There can be only one center of gravity," (p. 35). Marine Corps Doctrinal Publication (MCDP) 1 refers to Clausewitz and joint doctrine in defining the center of gravity as, "Those characteristics, capabilities, or localities from which a military force derives its freedom of action, physical strength, or will to fight," obviously consistent with joint and Army doctrine (p. 131). Although MCDP 1 heavily emphasizes attacking critical vulnerabilities, Marine

Corps doctrine no longer departs from the rest of joint and service doctrine by equating centers of gravity with critical vulnerabilities. Despite this convergence, the preconception persists that there are significant differences between the various service definitions of center of gravity. For example, several recent studies cite the Marine Corps definition in the outdated Fleet Marine Force Manual 1, overlooking the 1997 MCDP 1, which superseded it (Eikmeier 1999; Lee 1999; Rainey 1999; Springman 1998).

Issues in Application

Either due to or in spite of doctrine, the utility and application of center of gravity has been a perennial source of debate and controversy. It is necessary to review contentious issues commonly associated with center of gravity and determine their relevance to this work.

One debate is whether there is only one center of gravity or if multiple centers of gravity can exist. This issue is discussed in contemporary studies. Giles and Galvin (1996) contend that there is one center of gravity per force (i.e., adversary), and the process model accompanying the monograph reflects this assumption. They advocate a process that eliminates candidate centers of gravity until only one remains. Others, such as Lieutenant Colonel Dale Eikmeier (1998) argue that recognizing multiple centers of gravity is more useful in modern planning. Clausewitz's own language seems to advocate a single source of power and strength, although he allowed in Book Eight that *ideally* there is only one and that directing all of your strength against other things could be justified when "exceptionally rewarding" (pp. 617-8). Later in Book Eight he refers to identifying the "enemy's *centers* of gravity" (emphasis added) (619). Major James

Rainey (1999) presents evidence from Clausewitz in support of both positions and suggests that the author himself would validate one position or the other, given the opportunity (p. 9). Major Seow Hiang Lee (1999) argues that at the root of the contention is a slavish adherence to the features of the physics concept that inspired Clausewitz, along with a strict, overly selective reading of *On War*.

The outcome of this study does not depend on the selection of one position over the other in this debate. Since current joint and Army doctrinal definitions provide for multiple centers of gravity, an agent should be able to accommodate solutions including either single or multiple centers of gravity. With sufficient knowledge, a computer-based agent can easily accommodate both views and a range of resulting behaviors. Learning agents can also be taught to follow the reasoning preferences of their "teachers"--resulting in agents that conform to a user's unique requirements. The modeling of examples later in the thesis identifies multiple *viable* centers of gravity in some cases. This is not intended to suggest that they all must be regarded as centers of gravity simultaneously. Rather, each selection is presented as *defensible* as a center of gravity based on the explanation given.

Another debate concerns whether the center of gravity must be a military force or whether other things might also be considered as such. In Book Eight, Clausewitz allowed that centers of gravity other than concentrations of military force can exist, such as a country's capital, the personalities of leaders, a principal ally, or public opinion (pp. 596-7). Schneider and Izzo (1987) argue that Clausewitz erred and misled readers in doing so. Their argument is predicated on the assumption that Clausewitz's physical analogy was meant to preclude these other candidates, and that consideration of these

sources of power were a result of Clausewitz himself misapplying the concept. Others take Clausewitz at face value, and accommodate such non-force-centric possibilities. Giles and Galvin (1996) provide for a range of strategic centers of gravity, including economic (e.g., the manufacturer of strategically important goods), controlling elements (e.g., a cabinet or dictator), and force compositions (e.g., alliances, cooperation among groups). A point of agreement remains, however, in that they remain consistent with Schneider and Izzo in their test for center of gravity suitability: "Can imposing your will . . . on the potential center of gravity candidate create the deteriorating effect that prevents your foe from achieving his aims and allows the achievement of ours . . . and will it be decisive?" This test is a useful one for computer-based modeling to discriminate between center of gravity candidates, regardless of preference for force-oriented centers of gravity or otherwise. The modeling presented in this thesis treats forces as the primary means of military operations. In recognition of current doctrinal definitions however, additional sources of strength are also considered as points of departure for center of gravity analysis, sometimes leading nonetheless to a force that provides the strength or capability under consideration.

An additional question concerns whether separate, potentially different, centers of gravity exist at the strategic, operational, and tactical levels. Lieutenant Colonel Ralph J. Perry argues that the distinction is unnecessary because levels of warfare are no longer discrete, citing that actions taken in a tactical context can influence what might be considered a strategic center of gravity (2000). However, this seems more apt as evidence that there are linkages between centers of gravity at different levels, than as an argument against differentiating between centers of gravity at each level. The usefulness

of analyzing the factors relevant to both the operational and strategic context has been well established. Schneider and Izzo demonstrate the relationship between German strategic and operational centers of gravity in the Manstein Plan (1987). The USAWC methodology (Giles and Galvin 1996) begins with strategic center of gravity analysis and provides for further determination of operational centers of gravity in the event that the scenario involves military operations. This approach provides a detailed, practicable method that is particularly applicable at the strategic level of analysis. It is currently in use for educational purposes at several senior service colleges (Keppler 1995). Recently, the applicability of this distinction provided an excellent start for agent development at the USAWC (Bowman 2001). This method lacks usable detail, however, regarding considerations for operational center of gravity selection. This thesis complements the analysis of Giles, Galvin, Keppler, and Bowman by identifying the operational considerations and by formalizing a problem-solving methodology based on them.

A recent trend in center of gravity thinking is toward systems thinking. In "The Enemy as a System," Colonel John Warden describes the enemy as a system consisting of numerous subsystems (1995). He then uses this perspective to propose a five-ring model of the elements of national power and its sources (p. 47). He offers this as an applicable framework for strategic center-of-gravity determination. This systems approach is succinctly described by Lee in the aforementioned Air Command and Staff College paper: "Systems thinking refers to the attempt to view the world in terms of irreducibly integrated systems. It focuses attention on the whole as well as on the complex interrelationships among its constituent parts" (1999, 23). The influence of systems theory is clearly seen in a number of recent works that propose systems-based

approaches to center of gravity application (Eikmeier 1999; Johnson 1998; Lee 1999; Marich 1995). These models offer valuable insight into approaches and considerations that can be taught to intelligent agents, but do not directly inform the modeling presented later.

Relationship to Other Planning Concepts

The concept of center of gravity is inexorably linked to other planning concepts. A review of the literature regarding these related doctrinal terms is helpful in disambiguating the concept of center of gravity for the purpose of this thesis, and also helps clarify what is excluded from consideration in the model presented here.

Ends, Ways, and Means

Ends, ways, and means provide a basis for clarifying the center of gravity's definition, role in operational art, and distinction from other concepts. Doctrine identifies center of gravity as the essential beginning in operational art. Operational art is the employment of military forces to achieve strategic goals through the design and conduct of strategies, campaigns, major operations, and battles (DOD 2001). The ends, ways, and means of operational art involve identifying the military aims to be accomplished (ends), a sequence of actions to produce that result (ways), and the application of resources to realize those actions (means). The goal of operational art is to protect friendly centers of gravity and to defeat enemy ones to achieve operational ends.

Ends, ways, and means inform critical distinctions among the concepts needed for reasoning about centers of gravity. This understanding is useful to both human reasoning

and to modeling for a computer-based agent. Distinguishing among ends, ways, and means provides a way to meaningfully relate important features of an operation to one another and provides a basis for recognizing what makes a strength a center of gravity. Centers of gravity must be selected from among the means that can perform the ways of the operation to accomplish the ends. Identification and evaluation of those means, informed by the ends and ways, guides analysis later in chapter 4.

Critical Factors

Some center of gravity methodologies refer to the need to properly apply the concept of critical factors with respect to both the friendly force and enemy force. *Critical factors* is a term often used to refer to both critical strengths and critical weaknesses (Vego 1998). In this terminology, *critical strengths* are capabilities that are vital to the accomplishment of a given or assumed military objective. As discussed, centers of gravity are generally understood as sources of strength and so are chosen from among these critical strengths. *Critical weaknesses* are things that might ordinarily be sources of power but have serious deficiencies that that can adversely affect the outcome of the given or assumed military objective. This terminology should be recognized as an alternative way to describe and distinguish important features of the means of an operation. To acknowledge that centers of gravity are selected from among critical strengths is equivalent to the recognition that centers of gravity are the means that are most important to achieving operational ends. Further considerations of this aspect of operational art uses the ends, ways, and means terminology to identify the relevant critical strengths (i.e., means) and relate them clearly to ends and ways.

Critical Vulnerabilities

Some further distinguish the concept of *critical vulnerabilities* (Izzo 1988; Vego 1998). There are generally two sources of critical vulnerability (Vego 1998). One type is an exploited critical weakness--one that is inadequate or highly susceptible to enemy actions. The other source is a critical strength that lacks adequate protection or support and is thereby vulnerable to enemy attack. Centers of gravity are found among strengths, not among critical weaknesses or critical vulnerabilities (Izzo 1988). A common misstep in center of gravity analysis is to recognize a salient vulnerability and subsequently identify it as a center of gravity out of the temptation to attack it. This thesis avoids selection of vulnerabilities by considering only the strengths that can achieve operational ends.

Decisive points and Objectives

Decisive points are also related to centers of gravity in an important way. FM 3-0 defines *decisive point* as "a geographic place, specific key event, or enabling system that allows commanders to gain a marked advantage over an enemy and greatly influence the outcome of an attack" (p. 5-7). It goes on to point out the relationship between decisive points and centers of gravity, stating that they are not centers of gravity themselves, but are the keys to attacking or protecting them (p. 5-7). JP 3-0 states the same relationship between the concepts (p. III-23). Decisive points are often critical vulnerabilities that provide opportunities to weaken centers of gravity (Vego 1998).

The distinction between center of gravity and decisive point is potentially confusing for a number of reasons. Features that can appear to be sources of strength by one line of reasoning could be decisive points that are key to attacking or protecting a true center of gravity. Sometimes the distinction relies on a matter of opinion regarding which is the true source of strength. A common variation of this is the selection of localities as centers of gravity that are not in themselves sources of power. Such selections are difficult to justify as the means that can (themselves) accomplish ends. However the persistence of such bias is understandable given the history of definitions that include "localities" in them. In addition, locations are often so closely related to a source of power that they are viewed as acceptable expressions of the same thing, and therefore acceptable candidates for center of gravity. This is not faithful to the definition of center of gravity, however. All definitions identify the center of gravity as a source of power, or as treated here, the most significant means of an operation. The most recent and most authoritative doctrinal definition of center of gravity, found in the September 2001 edition of JP 3-0, removes the reference to localities. Recall that the current doctrine revises the wording of the joint definition to replace "localities" with "sources of power" (p. III-22). This helps emphasize the proper relationship between center of gravity and decisive point, and provides an authoritative argument against selecting geographic areas as operational centers of gravity. Insofar as operational art is the employment of military power to achieve strategic objectives, localities are not considered here as the means of military operations that perform the ways that achieve ends.

Objectives are usually selected from among decisive points. Such objectives help weaken enemy centers of gravity. An objective is not often itself a center of gravity because centers of gravity are usually too strong to attack directly. Much of the value of decisive point comes in identifying ways (either direct or indirect) to attack or threaten centers of gravity (Schneider and Izzo 1987). Once these decisive points are identified, they become objectives and are the tangible goals of the operational design.

Role in Operational Art

This review of center of gravity with respect to these related concepts underscores the reality that their selection and application lies squarely in the realm of military art. Despite the fact that exact agreement on definition and use of the center of gravity is practically impossible, the concept's role in operational art is no less valued in doctrine. Notwithstanding variations in definition and application, the center of gravity is a central concept in operational art, providing the focus of planning and the basis for selecting other related operational concepts that ultimately determine the operational design. Contemporary understanding of the concept could benefit from more rigorous definition and consistent and application. The modeling in this thesis indirectly provides a way to specify and evaluate such an effort.

The application of science (in this case, agent development) to this art is inherently problematic, but not impossible. A learning agent that can accommodate varying approaches to definition and determination of the center of gravity transcends individual preferences by focusing away from definition and squarely on utility. If the agent is not dependent on any particular view of center of gravity and its relationship to

these other planning concepts, then human experts can examine the results of the AI, agree or disagree with outcomes and reasoning, and adjust performance accordingly. An expert might agree with a center of gravity conclusion but disagree with the rationale given by the agent, or vice versa. This is evident in the following chapters dealing with methodology and analysis of results.

Case Studies for Center of Gravity Determination

Historical case studies are used as examples for this work. While there are a great many potential historical operations that could inform modeling, one source offers scenarios specifically written to be a basis for center of gravity analysis. The USAWC elective course, "Case Studies in Center of Gravity Determination," employs historical analysis of selected campaigns for student study, and provides vetted histories containing information relevant to center-of-gravity determination for each campaign. The scenarios used in the course include Falklands, Grenada, Inchon, Korea (post-Inchon), Leyte, Malaya, Okinawa, Panama, Philippines, Sicily, and Somalia. Among these USAWC studies, the US invasion of Okinawa (1945) and Operation Just Cause in Panama (1989) meet the criteria set out in the thesis limitations in that they exemplify state versus state conflict in conventional war. Thus they are used as examples in this thesis.

The Okinawa campaign represents a conflict involving a single nation state on each side--the US versus Japan in the final campaign of the war in the Pacific. The USAWC Study, *Okinawa: The Final Campaign* (USAWC 2001b) provides comprehensive information regarding the strategic and operational factors relevant to centers of gravity. The Leavenworth Paper, *Japan's Battle of Okinawa, April-June 1945*

(Huber 1990) was also used as a source. Panama provides a second historical example of state versus state conflict--the US versus Panama in Operation Just Cause. The USAWC Study, *Operation Just Cause: Panama 1989* (USAWC 2001c), provides information regarding the strategic and operational factors relevant to centers of gravity.

Summary

This chapter has surveyed two areas of study that intersect in this thesis--the technical field of AI and the military concept of center of gravity. The overview of the literature in AI defined the field and identified the relevant research in intelligent agents. A review of the doctrine and literature pertaining to center of gravity defined the concept and identified the issues that pertain to agent building. This review sheds light on a supporting research question: Are there generally applicable procedures for center-of-gravity determination? Neither doctrine nor academic writing offers a compelling or authoritative generally applicable procedure for this. The procedures, identified in the USAWC COG monograph and related work (Keppler 1995; Giles and Galvin 1996), provide a procedure for strategic centers of gravity, but no comparable model has been advanced for operational center of gravity. Instead of starting with an established procedure, a general one was discovered as a result of this research while taking into account the considerations discovered in the doctrine and literature.

The next chapter, “Research Methodology,” presents the research methodology that was used to model center-of-gravity determination and answer the research questions. The methodology incorporates this literature review by drawing from many of

these works to find the considerations that bear on center of gravity selection, as well as methods for identifying centers of gravity for historical scenarios.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

This chapter describes the research methodology used to answer the primary research question, Can computers be taught to conduct center-of-gravity determination using current learning agent technology? The overall strategy is to answer the secondary research questions that follow from the primary question, as outlined in chapter 1.

The research methodology consists of two broad steps or activities. First, *center of gravity modeling*, using the Disciple learning agent task reduction methodology, generalized a problem-solving procedure for center-of-gravity determination that is usable by a Disciple agent. Then an *evaluation of results* tested the validity of the modeling by submitting all results to experts for independent evaluation. Modeling and evaluation was done based on the two historical case studies introduced in chapter 2: Okinawa and Panama.

Center of Gravity Modeling

Center-of-gravity modeling is the creative activity in the research methodology. Its purpose is to discover the concepts and procedures needed to build an agent and to directly answer the secondary research question, Can a problem-solving method for center-of-gravity determination be formalized for use by a computer-based agent? This modeling applied concepts discerned from the review of the literature regarding center of gravity to the selected historical case studies. The model was first created based on one scenario, then generalized for application to a new one. This addresses another

secondary question, Will the modeling apply to multiple scenarios? The literature review provided a basis for discovering the concepts that need to be represented and perspectives on how to perform this reasoning. The historical case studies provided the grist for exemplifying the considerations used in selecting center of gravity.

The Disciple learning agent, introduced in earlier chapters, is the target application for this modeling. In order to clarify the form and purpose of the modeling, it is necessary to first present the basics of Disciple agent development. The following section presents the Disciple learning agent development process (Tecuci 1998) as it relates to the research methodology.

Target Technology: Agent Development in Disciple

The modeling in this research is intended for use in developing Disciple learning agents. This section presents the fundamentals of that technology. The overall process for agent development in Disciple and the tools used in that technology are presented in order to demonstrate how the problem-solving procedure presented in this thesis applies in the motivating technology.

The Disciple learning agent is a suite of software components used to develop an intelligent agent. The agent development environment consists of three main components: 1) A *graphical user interface* (GUI) that allows a user to communicate with Disciple in a user-friendly manner; 2) The *teaching, learning and problem-solving component* which performs knowledge formation and problem solving, containing tools for rule learning, rule refinement, mixed initiative problem solving and autonomous problem solving; and 3) The *knowledge base management component,* which contains

tools for managing the knowledge base and for importing knowledge from external knowledge repositories (Tecuci, 1998). All of these components are utilized in the construction of learning agents such as the one proposed here.

A Disciple agent for determining centers of gravity must have at least a minimal amount of knowledge about the world and the center of gravity domain. This is called a generic object ontology. This is the portion of the knowledge base that defines the high-level (more abstract) concepts discovered in literature review and case study analysis. Examples of such concepts used in this domain include those of opposing forces and operational tasks, just to name a few. The ontology must also include the features that these objects may have. Features for a force might include information such as size and capabilities. Disciple manages the acquisition and maintenance of this knowledge through a graphical user interface called a scenario elicitation tool. This enables experts to teach an agent the features of a scenario for the purpose of center-of-gravity determination without the need to directly interact with the object ontology.

In addition to the knowledge of a scenario represented in the ontology, an agent also needs a description of the logic to be used in reasoning--in this case for determining centers of gravity. This is referred to as the reasoning model. The product of this research is a proposed reasoning model for determining operational centers of gravity. The Disciple modeling approach is based on a task-reduction/solution-synthesis paradigm (Tecuci 1998). In this technique, a task to be performed is successively reduced to simpler tasks until the tasks are simple enough to have immediate solutions. To compose a complete solution to the original question, the solutions for each step are successively recombined into a sort of explanation. Thus the answer provided by the Disciple agent

always comes complete with a justification. The modeling in this thesis uses this task reduction paradigm to describe center-of-gravity determination so that it can be later taught to an agent.

The modeling methodology begins by identifying the overall task to be conducted and specifying a question and answer that leads to the identification of one or more simpler tasks. Each new task is then decomposed in a similar way, identifying either new questions and answers or a solution that can be conclusive or inconclusive regarding the overall task. For an agent to make best use of an example to learn a general task, the modeling of that example must do this task reduction in the smallest, most incremental steps practicable, avoiding "leaps in logic" that fail to articulate important reasoning steps. Such simplifications can lead to spurious reasoning on new scenarios.

Task reduction modeling provides several benefits. One is that it is an effective knowledge engineering technique that emulates a sort of interview between a novice and an expert. When thoroughly conducted, it can very effectively describe complex reasoning. The modeling in this thesis also serves the purpose of preparing for agent construction because this is exactly how the agent initially learns the new domain. The user, as expert, identifies tasks to be solved to the agent and "teaches" the agent what to do with that task by identifying the question that naturally obtains from it, the answer, and the result--either a new task to decompose or a conclusion of some sort. The domain modeling in this thesis can provide the basis for just this sort of agent development.

The Disciple components that rely upon this modeling are implemented as a number of related software "tools" that handle specific aspects of agent development. Using the Disciple user interface, these tools require little in the way of technical

(knowledge engineering) skill. Disciple is designed so that agents can be developed entirely by subject-matter experts, with no or very limited assistance from a knowledge engineer.

Agent development generally proceeds in five phases (figure 1). During the scenario specification phase, the scenario elicitation facilities are used to specify the concepts that define a specific historical case. Next the domain modeling tool is used to model the reasoning using the domain modeling described above, using English phrases that refer to elements from the scenario description. In the next phase, rule learning, general problem-solving procedures are learned based on each task reduction using the rule-learning tool. Because the rules are imperfect at the beginning of agent development, the agent allows for further refinement so that it can make the best use of them in future situations. This is done with the rule refinement tool. Finally, if all of the other steps are conducted to some degree of completeness, the problem-solving tool can be used, so that the agent can identify centers of gravity for a scenario either autonomously or with the cooperation of a human user.

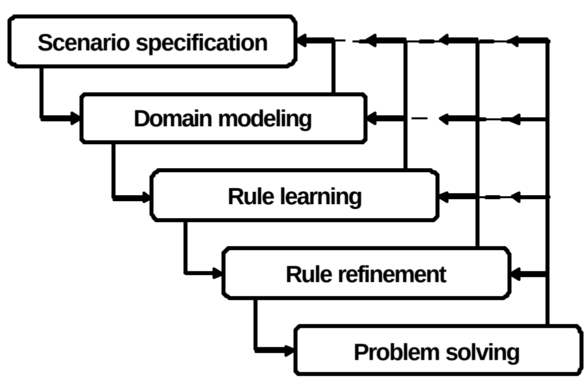


Figure 1. The Main Phases of Agent Development

After the Disciple agent has been trained based on at least one example, it can be used in autonomous problem-solving mode, either by the expert who has taught it or by another user. The problem-solving facilities in Disciple enable the user to supervise agent performance on a wider range of examples and to use the rule refinement facilities to teach more exact problem solving.

The agent development phases depicted follow a natural sequence from one phase to the other, because some degree of completion is required in one step before moving on to the next. However, it is possible and necessary at times to also return to a previous phase to complete or refine actions, as indicated by the back arrows in figure 1. For example, it may be necessary during problem solving to define a new task reduction that requires additional modeling, rule learning, and rule refinement.

Task Reduction Modeling of Center of Gravity

The above overview situates the modeling done in this thesis in the intended development of learning agents. The task reduction method used to teach an agent is the same method used in this research methodology to model the current problem. This task reduction modeling must be applied to a concrete example. Thus initial modeling was done based on one example of state versus state conflict in conventional war (i.e., the Okinawa campaign). The resulting model was next generalized for application to a new scenario. Finally, a second campaign (i.e., Panama) was analyzed by applying that general form, in much the same way as a Disciple agent generalizes and applies a learned example in rule learning and refinement. Each of these modeling activities is presented in greater detail below.

Modeling the Initial Example

Task reduction modeling for any problem begins with the identification of the overall task to be conducted. In this case, the overall task was to identify operational center(s) of gravity for a scenario (i.e., Okinawa in the initial modeling). Next, a question and answer related to that task was identified, which led to the identification of one or more simpler tasks that contribute to solving the higher task. In task reduction, the question and answer serve two purposes. For the purpose of modeling, it allows the modeler to “think aloud” and articulate the process of identifying a sensible line of reasoning that enables the identification of the next task(s) to be conducted. This makes the process of modeling and teaching an agent similar to instructing a student. The second benefit of the question and answer approach to identifying subordinate tasks is that the agent can communicate with the user by re-using this same information in both proposing new lines of reasoning (articulating the question and answer that was inferred) and in explanation generation.

For this modeling, initial questions dealt with two thesis limitations that scoped the research. The first set identified the scenario as a conventional war scenario, and the next identified each participant as a single-member force (as opposed to an alliance of some sort). Once scoped in this way, additional questions and answers successively simplified the tasks, producing a logically coherent approach to solving the overall task.

Each time a question and answer was determined, the answer informed the identification of one or more new tasks that contributed to answering the parent task. Each new task was decomposed in a similar way, identifying the questions that naturally

followed from new tasks, the answers to those questions, and a resulting task that provides a simpler step that contributes to the problem. In each case this result was either a new task to further decompose or a conclusion of some sort (which could be conclusive or inconclusive regarding the overall task to identify a center of gravity). Task decomposition stopped only when all tasks were completely decomposed, leaving only "conclusions" that represent the end points of the various lines of reasoning.

A graphical notation was used to record the task reduction used in the initial modeling and to support all of the subsequent modeling in the thesis. Its general form is shown in figure 2. Arrows indicate the flow of task decomposition and the logic of the models is generally read along these lines. Tasks are identified in single-bordered boxes. Questions are depicted in single-bordered rounded boxes, and answers are depicted in double-bordered rounded boxes. In addition, questions and answers are distinguished by italicized text. A complete task decomposition step includes a beginning task, a question and answer, and a result. The result is either a new task to be decomposed or a solution, depicted as a double-bordered box.

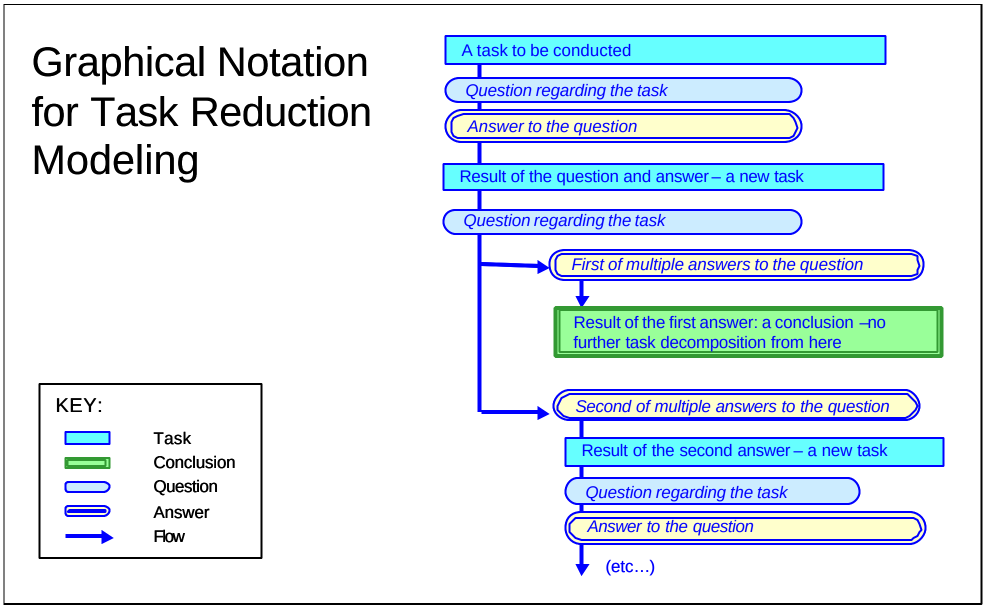


Figure 2. Graphical Notation for Task Reduction Modeling

Generalizing the Example

The next modeling activity involved generalizing from the first example. *Generalization* is a process of deriving a generally-applicable procedure from example problem solving. This was done based on the task reduction model of the Okinawa scenario by *parameterizing* the model steps and by formalizing additional logic left implicit in the example. Parameterizing scenario-specific information involved identifying all of the detail that was unique to the Okinawa scenario and replacing each reference to such detail with placeholders called *parameters*. Parameters designate places for scenario-specific detail in a generalized form. Parameters were used consistently so that each reference to the equivalent concept in the example was replaced by the same parameter. For example, in generalizing the Okinawa model, every occurrence of the concept "establish a foothold on Okinawa" in the first model was

replaced by a parameter, *<Operational Aim>*, wherever that concept occurred to generalize that scenario-specific information.

The following conventions were used for parameterizing (figure 3). Expressions in angle brackets designate simple parameters that can be replaced with scenario-specific instances. Such expressions (e.g., *<Opponent_1>* and *<Operational Task>*) can be replaced with scenario-specific information in application (e.g., “US_1945” and “seize Okinawa”). Terms in square brackets designate optional expressions. For example the expression *[during the <Phase Name> phase]* allows for the inclusion of this information only when phases are being considered. Only if the overall term is used should the parameter within (i.e., *<Phase Name>*) be used. Terms in braces indicate a choice to be made among alternatives, which are separated by commas. The choice should remain consistent within each application of the model. For example the expression *{will to fight, freedom of action}* allows for the selection of either the expression “will to fight” or “freedom of action.”

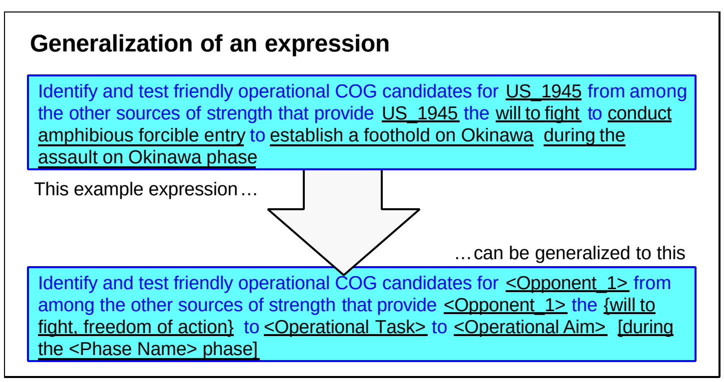


Figure 3. Generalization of an Expression

Generalizing the first model uncovered additional problem-solving logic that was implicit in the first example, which should be made explicit for clarity and application to new cases. Although most of the problem-solving logic in the first scenario was explicit by virtue of the task reduction method, additional logic was added to specify places where decisions were made and where only one alternative could be modeled in the example. Such decisions were added to the general model. These elaborations included decisions to be made or processes to be repeated. Completing the logic of the general model in this manner resulted in a compact, unambiguous flowchart-style representation.

The depiction of the general model required the use of some additional flow control symbols, depicted in gray in the modeling (figure 4). In some cases, task reduction proceeded based on some condition that was not explicitly provided in the task reduction. To more compactly represent these determinations, diamonds depict the determination of the condition and indicate the subsequent flow of the reasoning. At such points, only the logic that continued from the indicated condition was executed. There are other occasions where the same logic was repeated for multiple valid answers to a previous step. This repetition is indicated with rounded rectangles. In such cases when multiple answers were obtained, all subsequent reasoning from that point forward in the flow of the logic was repeated for each answer.

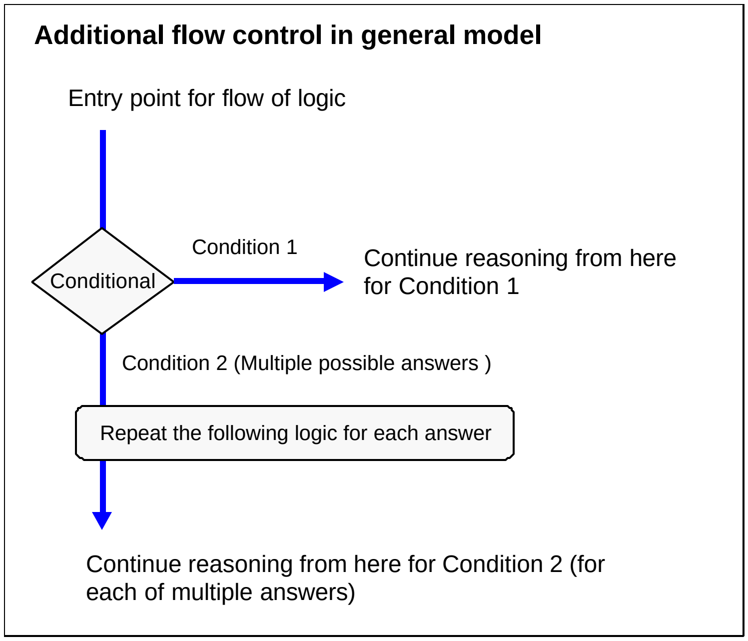


Figure 4. Flow Control Symbols in General Model

Application to a New Case

The creation of a general model distilled reasoning behind the example scenario to be applied to a second scenario in order to test the general applicability of the method. This application was conducted on the Panama scenario as a test case. The application of the general task reduction model for operational center-of-gravity determination to the new example involved following the logic represented by the general model and instantiating the parameters of that model with the appropriate aspects of the new case.

Instantiation is the opposite of generalization, described in the previous section. In instantiation, parameters in a general expression are replaced with the appropriate information from the scenario under consideration. Figure 5 demonstrates the use of the general form derived in the generalization example (figure 3) to instantiate a new

expression that is valid for the new case. In this example, the parameter *<Operational Aim>* was replaced by the new concept "disarm and dismantle the PDF." All such replacements were done consistently wherever that parameter occurred throughout the remaining flow of the logic from that point. Following the logic of the general model and doing consistent instantiations in the manner described should (in principle) generate a coherent new analysis of a new scenario. This is the process that was used to analyze the new scenario.

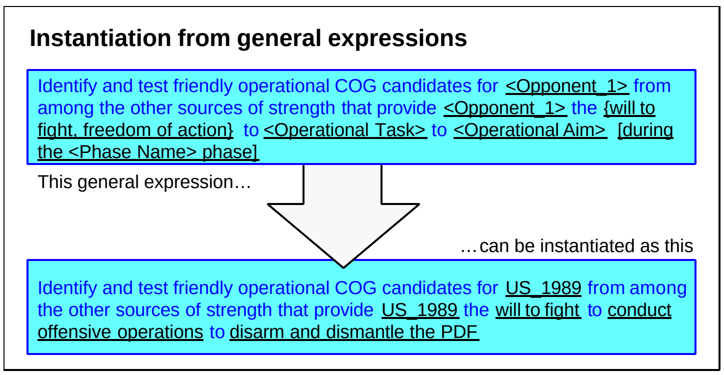


Figure 5. Instantiation from General Expression

Modeling center-of-gravity determination using Disciple's task reduction methodology contributes to the thesis by answering the research question, Can center-of-gravity determination procedures be modeled for use by a computer-based agent? This evidence, when combined with the review of the literature and historical case studies, completes the support for answering a secondary research question, Can a problem-solving method for center-of-gravity determination be formalized for use by a computer-based agent? This aspect of the research methodology also addresses the supporting

research question, Can the modeling apply to a scenario that involves a state versus state conflict?

Evaluation of Results

The second activity in the research methodology is an evaluation of the results obtained in modeling. This step tested the validity of the results of modeling by subjecting the results obtained from the modeling to expert evaluation. This evaluation provides the means to answer the last of the three secondary research questions, Will the modeling produce credible results?

The results of modeling were subjected to expert evaluation to determine the credibility of results. Credibility was measured by addressing two further subordinate questions. The first, Does the modeling lead to centers of gravity for selected case studies that are consistent with the choices of experts, provided a means to judge whether the models enable conclusions comparable to those of experts. A second, Does the logic of the modeling appear to represent valid reasoning about centers of gravity, tested whether the logic of the model approximates the reasoning of human experts.

This was accomplished using independent evaluations of results by subject-matter experts. The data for this evaluation was gathered from a sample of faculty members from the USAWC and CGSC departments that teach operational center of gravity. The experts were solicited from the Department of Joint Military Operations at CGSC and the Department of Military Strategy, Planning, and Operations at USAWC. The experts were presented with the results of modeling in a narrative identical to that which the agent could produce using the solution synthesis explanation technique related to task

reduction, described previously. The evaluation instruments asked the evaluators to judge the correctness of the determinations by responding to questions throughout the explanation. Each evaluator was given a separate evaluation instrument for each scenario at the same time and was asked to complete both. The questionnaire used a five-point Likert scale to measure the extent to which a person agreed or disagreed with statements regarding various aspects of the analysis. In each instrument, the responses were assigned values as follows: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree. The full evaluation instruments are at appendix D.

Initial questions in the evaluations pertain to the background of the evaluator, including military background (section I), as well as familiarity with center of gravity and familiarity with the historical scenarios (section II). These questions were used to qualify evaluators as expert. Only evaluators with some experience teaching operational center of gravity at the staff college or senior service college level were included in the analysis. Evaluators with 0 years teaching the concept at those levels were excluded from analysis. Evaluator expertise was also screened using responses to the questions, "I am familiar with the concept of center of gravity," and "I consider myself qualified to determine operational centers of gravity." Only those evaluators that agreed or strongly agreed with each of those statements were included in the analysis.

In section III, the evaluators read the analysis of the given historical scenario in a narrative form generated entirely from the modeling results. The questionnaire presented conclusions regarding center-of-gravity determination following the logic of the model and elicited responses about each determination. Evaluators judged individual center-of-gravity determinations by agreeing or disagreeing with the acceptance or rejection of a

center-of-gravity candidate (and in some cases the failure to find any candidate for a particular source of strength). Where center of gravity candidates were identified and judged to be valid selections, evaluators responded to the question, “I agree that this is a valid center of gravity for this scenario.” Where center of gravity candidates were eliminated as centers of gravity, evaluators responded to the question, “I agree that this is NOT a valid center of gravity for this scenario.” There were also cases where the example modeling failed to find potential centers of gravity (where perhaps some should have been found). Where the example modeling considered no candidates of a particular type, the evaluator responded to the question, “I agree that no center of gravity candidates of this type should be considered in this situation.” If the respondents agreed or strongly agreed more than 50 percent of the time with each of these three possible statements regarding the conclusions, then the model was judged to identify centers of gravity consistent with those identified by human experts based on an evaluation of individual center-of-gravity determinations.

The evaluators also responded to questions regarding agreement or disagreement with the explanations for each finding. These questions enabled an evaluation of the thought process reflected in the reasoning independent of agreement or disagreement with the conclusions themselves. Where center-of-gravity candidates are identified and judged to be valid selections, evaluators responded to the question, “The rationale presented for choosing this center of gravity is valid.” Where center of gravity candidates were eliminated as centers of gravity, evaluators responded to the question, “The rationale presented for rejecting this center of gravity is valid.” If the respondents agreed or strongly agreed more than 50 percent of the time with the above statements,

then the model was judged to represent valid reasoning about centers of gravity based on an evaluation of individual center-of-gravity determinations.

Following the evaluation of individual findings in section III, the evaluators provided an assessment of the overall performance of the model. In section IV, evaluators responded to the statements, “Overall the right center of gravity candidates were considered,” “Overall the right center of gravity selections were chosen,” “Overall, centers of gravity were chosen for valid reasons,” “Overall, centers of gravity were eliminated for valid reasons,” and “Overall, the rationale for choosing centers of gravity was valid.” This provides a measure of overall expert approval of the model’s performance. These responses were also used as a measure of model correctness, as an overall indicator of support for each of the indicated measures of credibility. Greater than 50 percent agreement (agree or strongly agree) supports a determination that results and rationale are credible as applicable for each question topic.

Completed instruments were collected and screened. Respondents who were not qualified as expert according to the criteria specified above were eliminated from the data set. The remaining data from qualified evaluations was recorded in separate tables of responses for each scenario (tables 3-5, appendix E). The data for question 1 represents the total years of military service. Question 2 is the combined number of years the respondent has taught operational center of gravity at the staff college and senior service college level. The remaining answers are the numeric values of the responses to the scaled questions. The values 1 through 5 represent the Likert scale responses presented earlier. A zero represents the response “not applicable” and a blank entry indicates that

no response was given. For each question, the mean, the median, and the mode were calculated and included in the tables.

In addition to collecting the raw data from each instrument, responses for questions of the same type from both scenarios were aggregated and described (tables 6 and 7, appendix E). Table 6 records the combined responses to the section IV questions from both instruments. For each question, the raw combined number of responses (i.e., *strongly agree, agree,* etc.) is recorded and the distribution of the response types is also shown (as a percentage). An additional set of percentages shows the distribution of responses into more general categories of "Agree" (i.e., combined *agree* and *strongly agree* responses) and "Do not agree" (i.e., combined *neutral, disagree,* and *strongly disagree* responses). For this data the statistical mean, median, and mode for each question type were calculated and included as in the raw data.

Table 7 records the combined responses to the section III questions from both instruments, aggregated by question type. The table is organized in the same manner as table 6, showing number of each response type, distribution of responses, and the statistical mean, median, and mode for each question type. The table aggregates the responses for seven groups of like questions. The group "Selection of a COG [center of gravity]" represents the aggregated responses to all of the statements, "I agree that this is a valid center of gravity for this scenario," (Panama questions 11, 20, 24, and 27, and Okinawa questions 11, 26, 29, 34, and 46). "Selection of a COG from among forces" represents the aggregated responses to the same statements, but only in cases where the candidate was considered in the portion of the model that considers forces (Panama questions 11 and 20, and Okinawa questions 11, 26, 34, and 46). "Selection of a COG

from capabilities or other sources of strength" represents the set of questions complementary to those in the previous set. In this set, the candidates were analyzed in the portion of the model that considers capabilities and sources of strength that provide freedom of action or will to fight (Panama questions 24 and 27, and Okinawa question 29).

The group "Rationale for choosing a COG" represents the combined responses to the statement, "The rationale presented for choosing this center of gravity is valid," (Panama questions 12, 21, 25, and 28, and Okinawa questions 12, 27, 30, 35, and 47). The group "Elimination of a candidate as a COG" represents the aggregated responses to the statement, "I agree that this is NOT a valid center of gravity for this scenario," (Panama questions 8 and 14, and Okinawa questions 8, 14, 17, 23, 37, 40, 49, and 52). The group "Rationale for eliminating a candidate as a COG" represents the combined responses to the statement, "The rationale presented for eliminating this center of gravity is valid," (Panama questions 9 and 15, and Okinawa questions 9, 15, 18, 24, 38, 41, 50, and 53). The last group, "No candidate should be considered for this situation," represents the combined responses to the statement, "I agree that no center of gravity candidates of this type should be considered in this situation," (Panama questions 17, 18, 19, and 23, and Okinawa questions 20, 21, 22, 32, 33, 43, 44, 45, 55, 56, and 57).

This data supported a quantitative analysis of the credibility of the model's reasoning and conclusions, as measured by the extent to which the respondents agreed or disagreed with the above statements regarding overall and individual determinations. In addition, optionally included comments from the evaluators provided additional qualitative data to support interpretation of the quantitative findings. This data was taken

from section V (Comments) and from the “notes in the margin” included by evaluators on a number of questionnaires.

This aspect of the evaluation determined the extent to which human experts judged the modeling to be correct. This provided a basis for judging whether the modeling performed agreeable center-of-gravity determination. In addition, independent of agreement or disagreement with the choices of centers of gravity, the evaluation also measured the acceptability of the model’s reasoning process to subject-matter experts. This instrument enabled evaluators to make these determinations based only on results and explanations, without exposure to the formal modeling or the details of the learning agent methodology. In fact, the instruments did not indicate at all that the analysis was based on modeling for computer-based reasoning. This controls for the temptation an evaluator might have to give undue credit or criticism to analysis performed by a computer.

Overall, evaluation of results contributes to the research goal by directly addressing the secondary research question, Will the modeling produce credible results? This can be answered in the affirmative if both of the research questions subordinate to that are also answered positively. The subordinate questions, Does the modeling lead to centers of gravity for selected case studies that are consistent with the choices of experts and Does the logic of the modeling appear to represent valid reasoning about centers of gravity, can be answered in the affirmative if greater than 50 percent of the responses to the appropriate questions indicate agreement (i.e., combined *agree* and *strongly agree* responses). Beyond that, stronger agreement (or disagreement) supports greater confidence in the conclusions that follow.

Validity

Several factors present challenges to the internal validity of the evaluation methodology. One of these is the heterogeneity of the respondents in the sample. While limiting the source of experts to faculty members of staff and senior service colleges who teach operational center of gravity provides a degree of consistency, this methodology fails to account for or control for potentially significant differences between respondents. A significant source of heterogeneity is the service background of evaluators. The faculty members included in the evaluation came from Army, Navy, and Marine Corps backgrounds. Considering the lingering service parochialism regarding the definition and application of the center of gravity discovered in chapter 2, this difference might influence the acceptability of the results to evaluators from different services. Another source of heterogeneity is whether the respondent is active or retired, and if retired for how long. It might have been beneficial to recognize and account for time spent away from actual practice.

Several considerations mitigate these sources of heterogeneity. One is that the evaluators were drawn from the departments of their respective institutions that are specifically responsible for teaching operational center of gravity. Thus they are presumably keeping abreast of doctrinal developments and use of the concept, and informing practice through the education of contemporary planners. In addition, while service definitions of the concept once differed significantly, there is now at least technical convergence of current service definitions as they come in line with joint doctrine (also discussed in chapter 2). Therefore there is a reasonable expectation that these faculty members are teaching a consistent and authoritative approach to the

concept. Notwithstanding these mitigating factors, whatever threat is posed by such sources of heterogeneity is recognized as reflecting normal differences that exist regarding the concept, which a learning agent model will need to address.

A second threat to the internal validity of the evaluation is the selection of respondents from only two sources: USAWC and CGSC. Selecting from these two schools exclusively is a type of convenience sample that was driven by accessibility to the faculty and the constraints of the research. While access to each of these departments was easy to accomplish, the time and resources available for this study did not permit a more thorough sampling from other senior service colleges and staff colleges.

All that can be done with regard to convenience sampling for the purpose of this research is to acknowledge the limitation. Given the opportunity to conduct another, more thorough evaluation, it would be beneficial to sample evenly from the equivalent departments of all service colleges and staff colleges. This would not only address the validity issue, but also present the opportunity to compare the views of different institutions. This is an opportunity for future work.

Summary

This chapter has laid out a research methodology that led to the development and evaluation of models for operational center-of-gravity determination. The methodology consisted of two activities: *center of gravity modeling* based on the Disciple learning agent methodology and an *evaluation of results* to test the validity of the results. The next chapter analyzes the results obtained using this methodology.

CHAPTER 4

ANALYSIS

Introduction

This chapter presents the modeling of operational center-of-gravity determination, addressing the primary research question, Can computers be taught to conduct center-of-gravity determination using current learning agent technology? A review of center-of-gravity literature and two historical cases reveal considerations for determining the operational center of gravity. This chapter first presents those considerations as an aid to understanding the modeling that follows. Then operational centers of gravity are analyzed for an example scenario based on those considerations and using the task reduction methodology. Next, based on that example, a generalized model for center-of-gravity determination is derived and explained. Then that model is used to analyze a new scenario to provide a basis for testing its validity for center-of-gravity determination and its applicability to intelligent agents. Then the expert evaluation of results is presented and analyzed.

A Model for Operational Center of Gravity Analysis

Considerations of Doctrine and Application for Modeling

As central as the concept of center of gravity is to operational planning (DOD 2000, V-3; DOD 2001, III-13), its application is a highly subjective and even contentious concept. As a review of the literature demonstrates (chapter 2), there is no definitive methodology for selecting the operational center of gravity in doctrine. Application of the concept is consequently dominated by perspective, preference, and bias. This is

obviously reasonable to a point, inasmuch as the elements of operational design exist mainly as conceptual aids to visualizing, planning, and realizing operational plans. Any viable center of gravity can form the basis for formulating and communicating coherent operational plans, even if reasonable alternatives have been rejected. The obvious issue that follows is determining what constitutes a defensible center of gravity candidate. When center of gravity choices run contrary to the definition of the concept, there is a risk of erroneously identifying related concepts (e.g., decisive points) that fail to identify the desired sources of enemy and friendly strengths.

Defensible and useful centers of gravity must therefore conform to some commitment as to what truly constitutes a source of strength and subsequently qualifies as a center of gravity. A center-of-gravity determination agent needs just this sort of rigor in order to produce sensible conclusions. The modeling in this thesis reflects insights discerned from the review of doctrine and literature. These insights, presented below, were revealed through the modeling of center-of-gravity determination for historical scenarios. Organized around the distinction of the “ends, ways, and means” of operations, the principles below constrain the reasoning process represented in the modeling, thereby defining the concept more concretely for an agent. What is important to this thesis is not so much the commitments themselves, but the demonstration that a point of view regarding center of gravity selection can be represented to the agent. Success here provides evidence that alternative approaches could likewise be represented if made explicit to the agent, thus accounting for differences among professionals regarding what should be considered a center of gravity.

As introduced in chapter 2, ends, ways, and means provide a basis for clarifying the center of gravity's definition, role in operational art, and distinction from other concepts. The technically authoritative definition of center of gravity in JP 3-0 defines the concept as "those characteristics, capabilities, or sources of power from which a military force derives its freedom of action, physical strength, or will to fight" (p. III-22). Doctrine provides this concept as an essential beginning in operational art. Operational art is the employment of military forces to achieve strategic goals through the design and conduct of strategies campaigns, major operations, and battles (DOD 2001). The ends, ways, and means of operational art involve identifying the military aims to be accomplished (ends), a sequence of actions to produce that result (ways), and the application of resources to realize those actions (means). The goal of operational art is to protect friendly centers of gravity and to defeat enemy ones to achieve operational ends.

Ends, ways, and means inform critical distinctions among the concepts needed for reasoning about center of gravity. This understanding is useful both to human reasoning and to modeling for a computer-based agent. Distinguishing among ends, ways, and means provides a way to meaningfully relate important features of an operation to one another and provides grounding in operational art for the modeling. Five principles contribute significantly to the modeling in this thesis: (1) ends, ways, and means are relative to each opponent's perspective; (2) centers of gravity are found among the means of the operation; (3) centers of gravity must be capable of accomplishing the ends of the operation; (4) the ways available for the operation constrain the means that should be considered; (5) centers of gravity are the means that matter most. Each principle is discussed in detail below.

Ends, Ways, and Means Are Relative to Each Opponent's Perspective

At any level of analysis operational designs, including friendly and enemy centers of gravity, must be determined relative to the goals (i.e., ends sought) and beliefs of each opposing side. The goals and beliefs that comprise an opponent's perspective influence center-of-gravity determination in two important ways. First, to be of use sources of power are considered centers of gravity according to their potential to fulfill some goal, and the opponent's beliefs about the situation influence that goal and what might be regarded as the relevant strengths. The second observation is that a complete consideration of centers of gravity for a scenario must result from analyses performed independently from each opponent's perspective, yielding potentially non-complementary "enemy" and "friendly" centers of gravity from the point of view of each.

It is aimless to consider operational centers of gravity independent of goals. This easily overlooked aspect is important to make clear when modeling the task for computer reasoning. A source of strength can be considered as a potential center of gravity if it can contribute to the accomplishment of the operational goal. As a practical matter, operational center-of-gravity determination is done relative to this goal. Sources of strength that cannot contribute significantly to the accomplishment of these aims are not useful candidates, no matter how strong they might otherwise be, because they have no significant role in operational plans that accomplish those aims. That centers of gravity must be capable of accomplishing the ends of the operation is a principle in itself discussed further in a later section.

It is necessary to account for the possibility that the goals assumed to be held by an adversary might differ from the actual goals of the adversary. In such cases what is regarded as the center of gravity for that adversary depends on which goals are considered. The common source of this disparity is assuming that enemy goals are equivalent to the opposition of friendly goals. A related error is failing to consider what the enemy *could* do to directly oppose the friendly goal because the assumed enemy goal is not to do that. For the purpose of planning friendly operations, it is sometimes prudent to assume that this is the case in order to ensure adequate attention to real or potential enemy centers of gravity that represent the greatest threat to friendly operations (irrespective of the lesser threat posed by the actual enemy goals). This would complement analysis based on actual or likely enemy goals, especially when they differ significantly, yielding potentially different centers of gravity. The set of resulting centers of gravity provides a more complete basis for planning. Centers of gravity identified without complete consideration of the goals of the opposing sides and the most significant threats to those goals could misdirect estimates and plans.

Beliefs are distinct from goals in that they represent what opponents perceive, whether valid or invalid, regarding any influence on the operation. Beliefs must be considered as well as goals. While goals determine the impetus for planning and action, beliefs influence planning and action by constraining matters, sometimes productively (e.g., discounting unlikely or infeasible actions) or counterproductively (e.g., overestimation and underestimation, failing to account for a source of strength). Consider that a source of strength may very well be a center of gravity regardless of what

the other side knows about it. Thus beliefs are important to this analysis as well and are another reason why multiple perspectives must be accounted for.

The Okinawa campaign provides an apt example of the role of both goals and beliefs. In that campaign, the US has as its goal to seize Okinawa by amphibious assault. Unknown to the US, Japan does not have as its operational goal the prevention of that. In fact, Japan's goal is to allow the US amphibious assault to seize the island and subsequently delay and attrit the US expeditionary force on the island. The perspectives of both the US and Japan at the time must be accounted for to fully analyze centers of gravity in this campaign. For example, from the US perspective, the enemy (i.e., Japanese) center of gravity during the amphibious assault phase might be expected to be Japan's 32nd Army because the US expects Japan to defend the beaches according to its doctrine. However Japan might regard its air forces, including the kamikazes, to be their own center of gravity during the same period because it believes its 32nd Army to be unable to effectively defend the beaches, and sees the greater strength to inflict damage on the US assault in its air forces. Therefore it is more thorough to refer to US or Japanese centers of gravity not independent of, but relative to the perspectives of each. In some cases it may be that the enemy center of gravity for one force is the friendly center of gravity for the other, and vice versa. It is imprudent to assume this however, as this example shows.

Agents can accommodate these considerations of perspective easily. The modeling demonstrated later in this chapter allows for the determination of centers of gravity independently from the perspective of each force (designated "friendly" for the context of reasoning) based on that force's operational goals. The "enemy" aim is

construed as the defeat or prevention of the friendly aims under consideration for the reasoning context, or perspective. By doing this, the model allows an agent to more fully account for the centers of gravity to be defeated and protected from both perspectives. The beliefs of the opponents are implicitly reflected in the nature of the scenario description given to an agent. These inputs can represent either a perfect “world view” of the scenario (a kind of historical hindsight whereby the agent knows everything) or the beliefs of the perspective being analyzed, depending simply on what the agent is given to believe.

<u>Centers of Gravity are Found Among the Means of the Operation</u>

The means, as used here, are the doers of the military operation. For the purpose of center of gravity analysis at the operational level, they are the effectors of the military instrument of power. A variety of means are available in an operation, with the most obvious type being military force. Schneider and Izzo (1987) point out that Clausewitz’ concept remains relevant in modern times as the “greatest concentration of combat force” (56). Other discussions in the literature stress that these means are typically concentrations of a force (Griswold 1986; Izzo 1988; Vego 1988; Keppler 1995). This is the most obvious source of strength for the employment of the military instrument of power to achieve ends. Other types of means might also be considered, if less frequently, such as weapons or systems. To stay true to the distinction of means from ends and ways, however, such things should only be considered as centers of gravity in circumstances where these are the true doers of the action that can win. When this is not

the case, the resource under consideration might nonetheless lead back to a force that employs it, suggesting a more exact center of gravity.

Means, as presented, clearly correspond to "sources of power" in the current doctrinal definition. Because "characteristics" and "capabilities" are mentioned together with sources of strength, these also bear consideration with respect to means. Doctrine is not at all clear what exactly constitutes either for the purpose of center of gravity, or in distinguishing exactly how they differ from one another. Consequently it is not immediately apparent whether there are characteristics or capabilities that can be typically regarded as categorically appropriate as centers of gravity. JP 3-0 does mention, as an example of such centers of gravity, the capability of dispersed military forces to mass and form a center of gravity. This is referred to as a potential center of gravity, and the proper focus of operational design mainly involves preventing its realization (p. III-22). Acceptance of this sort of strength as a center of gravity varies depending on the situation and the preferences of the one doing the analysis (or for the purpose of modeling, teaching the agent).

Of all of the "doers" available to a force for an operation, a center of gravity is the most significant. It is the one that can win for the force, in the sense that it is the source of strength that most directly contributes the ways that accomplish the ends. Center-of-gravity determination is a process of identifying candidates that fit this description and testing them for viability as centers of gravity. The next two principles concern ends and ways, guiding their consideration for informing the identification of candidates. Then the last principle revisits the concept of means to test candidates for viability.

Centers of Gravity Must Be Capable of Accomplishing the Ends of the Operation

Ends are an expression of what is to be accomplished to bring about the intended state of affairs, or operational end state. These aims are strongly linked to the center of gravity and guide its determination (Mendel and Tooke 1993). Ends guide center-of-gravity determination in all circumstances because a center of gravity can only be one relative to its importance in accomplishing those ends. Friendly centers of gravity are capable of performing the actions that will most directly lead to the end state. Enemy centers of gravity, if defeated, enable the accomplishment of the same. Thus ends limit the sources of power that should be considered as potential centers of gravity and drive center-of-gravity determination both in practice and for agent modeling.

It is of course possible that operations have multiple desired ends, and those ends could in turn beget distinct centers of gravity. For this reason, center of gravity modeling must be based on each identifiable operational end state. This is not to say that each aim should necessarily yield distinct centers of gravity, or even that a given aim must yield any center of gravity necessarily. It does seem however, that the rationale for choosing a center of gravity would be strengthened if that center of gravity could be derived based on multiple operational aims (and for multiple reasons in general). The modeling presented in this thesis does not attempt to weight center of gravity choices derived from multiple ends, but in future work this may provide a method for valuating and choosing among a number of choices.

The Ways Available for the Operation Constrain the Means that Should Be Considered

Ways are essentially sequences of actions that could accomplish an operational end state. They provide the linkage between the means of the operation and the ends to be achieved. In planning, centers of gravity drive the formulation of the specific ways or operational plans that attack the enemy center of gravity and protect the friendly. From this point of view, centers of gravity are determined as a condition for determining the ways.

The center-of-gravity determination that precedes development of operational plans, however, is not done in a vacuum. Before detailed planning, an expectation about the general ways appropriate to the operation implicitly guides center-of-gravity determination. This understanding can be as general as the anticipation that a forcible entry is or is not necessary, for example, but this expectation is critical to recognizing the sources of strength, both enemy and friendly, that bear consideration. As in practice then, computer agents must consider the general ways that are under consideration in order to properly consider centers of gravity.

The identification of center of gravity candidates should be informed by the range of such options that are available to the force to achieve the operational end state. Broadly construed operational alternatives such as "conduct amphibious assault" or "conduct defensive operations" constrain real world analysis and so also should for modeling used by computer-based agents. The nature of the aims and the situation determine the suitable operational alternatives. These alternatives help constrain (and guide) the exploration of the reasonable center of gravity candidates. Choosing centers of gravity informed by operational alternatives also strengthens the rationale of the center of

gravity selection, and ensures the relevance of that selection to both the situation and ultimately to the operational designs that are later generated. The agent modeling presented later in this chapter uses operational tasks to express the ways that constrain the determination of friendly and enemy centers of gravity.

Centers of Gravity are the Means that Matter Most

Having recognized that centers of gravity are found among the means of an operation and that ends and ways guide the consideration of means as such, it is necessary to return to the concept of means to determine more definitively how to distinguish centers of gravity. Distinguishing the means that qualify as the center of gravity is a matter of finding the means that can "win" or accomplish the operational ends (Izzo 1988). It is helpful to consider whether imposing one's will on the candidate will "create a cascading, deteriorating effect on morale, cohesion, and will to fight that prevents [an] enemy from achieving his aims and allows the achievement of [friendly aims]" (Mendel and Tooke 1993). In a systematic search for such a candidate, it is also necessary to narrow in on the most focused source of that power as possible, seeking the most localized concentration of strength that is capable of achieving the ends (Schneider and Izzo 1987; Izzo 1988; Keppler 1995; Giles and Galvin 1996). This is most notable when considering forces, where it is necessary to choose whether an overall force is the center of gravity, or if there is some subordinate unit or other sub grouping of the force that is better identified as the center of gravity. In such cases it is better to find the most specific sub-group of the force possible that can still be considered as a center of gravity.

Application to Okinawa

This section presents the results of applying the above considerations, using the task reduction approach, to model center-of-gravity determination for the Okinawa campaign. Because Okinawa is an example of conventional war between two states, this modeling addresses the supporting research question, Can the modeling apply to a scenario that involves a state versus state conflict? It also addresses the supporting question, Will the modeling apply to chosen historical scenarios? The results of the modeling are found at appendix B. This section explains the results and can be used as a guide to reading and understanding the formal model. Step numbers used in the description all refer to the steps of the Okinawa modeling in appendix B.

Brief Description of the Okinawa Campaign

Operation Iceberg, the invasion of Okinawa, was the largest amphibious invasion of the Pacific campaign and the last major campaign of the war in that theater. For the US, Okinawa was the last step in the Pacific theater island hopping prior to invasion of the Japanese mainland. Its capture would provide airbases from which air attacks on the Japanese homeland could be launched. The US Fifth Fleet Pacific Central Task Force needed to first seize the island by means of amphibious invasion and then defeat the defending Japanese 32nd Army in order to secure the use of the island as a staging area for the final assault against the mainland. The Japanese expected the US attack against Okinawa but did not expect to retain the island indefinitely. Instead, Japan's operational goal was to inflict the heaviest possible casualties on the invading forces in order to gain leverage for a more favorable end to the war. Therefore the Japanese ultimately decided

not to directly oppose the landings with the ground forces. Japanese air and naval forces, including Kamikazes, would interdict the invading force and the 32nd Army would defend the rugged terrain on a portion of the island. The battle lasted from 1 April to 22 June 1945, and was extremely costly for both sides. The analysis presented below is based on a detailed case study obtained from the USAWC Warfighting Studies Program, *Okinawa: The Final Campaign* (USAWC 2001b) and CGSC Leavenworth Paper #18, *Japan's Battle of Okinawa, April-June 1945* (Huber 1990). The reader is referred to those sources for more detail.

Center-of-gravity determination for the US Perspective

The modeling of Okinawa considered both friendly and enemy centers of gravity from the perspective of the US forces in that scenario (step 2.0). That is, the analysis was done according to the operational aims of the US in the scenario, so that a "friendly" center of gravity is a US center of gravity to be protected, and an "enemy" center of gravity is a Japanese center of gravity to be defeated. In the interest of space, the analysis was not repeated from the Japanese perspective, which would follow the identical pattern demonstrated here.

Recognizing that the aims of the US in the Okinawa campaign included both the seizure of the island and the defeat of the Japanese forces on the island, it was useful to distinguish two distinct phases for the purpose of analysis. Thus center-of-gravity determination was conducted separately for the seizure portion, called the assault phase for this analysis, and for the subsequent combat against Japanese defenders, called the ground operations phase here.

Ends and Ways of the Assault Phase

Analysis of the assault phase began with step A.3.0. The center of gravity can only be one relative to its ability to accomplish the ends of the operation for this phase. The operational aim of the US for this phase was identified as "establish a foothold on Okinawa." The ways under consideration for the accomplishment of this end state were expressed using a task in the current UJTL (DOD 1999), "conduct amphibious forcible entry."

Friendly Centers of Gravity for the Assault Phase

Potential friendly centers of gravity relative to this phase came from the sources of strength available to the US that could accomplish the action "conduct amphibious forcible entry" to accomplish the ends "establish a foothold on Okinawa," (step A.4.0). The analysis began with the forces available that were capable of this operation (step A.5.0). It was only necessary to consider the forces that could do this type of forcible entry operation. To begin with, the overall operational force, TF51 (Joint Expeditionary Force), was a candidate because it was the overall military force to be used by US during the assault on Okinawa phase and it was capable of amphibious forcible entry. This was determined to be a suitable center of gravity because the defeat of its capability to conduct amphibious forcible entry would have prevented the US from establishing a foothold on Okinawa. However it was ultimately rejected as a center of gravity because a more focused subgroup within this force was localized as a more definitive center of gravity (step A.5.3.0).

There are numerous potential sub groupings of TF 51. The most significant one down from the overall assault force is the group conducting the main landing to assault the Hagushi Beaches. Other groupings, including the forces assigned to assault the Kerama Islands, the deception landing at Minatoga, and the reserve forces all fail to qualify as being capable of achieving the aim. The main landing force assigned to assault Hagushi Beaches was found suitable for consideration because it was capable of conducting amphibious forcible entry during the assault on Okinawa phase to achieve the aim of establishing a foothold on Okinawa (step A.5.1.0). This was a viable choice for center of gravity because the defeat of its capability to conduct amphibious forcible entry could prevent the US from establishing a foothold on Okinawa (step A.5.2.0). Without the main landing force, there would not have been enough remaining forces with this capability to accomplish the aim.

Two further subordinate grouping of forces within the main landing force were considered but not found to be suitable centers of gravity (step A.5.1.1). TF53 (Northern Attack Force), and TF55 (Southern Attack Force) are the main components of the main landing force. While each was considered capable of conducting amphibious forcible entry during the assault on Okinawa phase to achieve the aim of establishing a foothold on Okinawa, neither was considered indispensable because the other half could carry on (albeit with difficulty) (steps A.5.2.1-2).

The modeling also considered capabilities (besides military force) available to the US to conduct amphibious forcible entry to establish a foothold on Okinawa (step A.6.0), but none were identified. Similarly, no sources of strength were found that provide the

US either freedom of action or will to fight to conduct amphibious forcible entry to establish a foothold on Okinawa (steps A.7.0.0-1).

Enemy Centers of Gravity for the Assault Phase

Potential enemy centers of gravity for this phase came from the Japanese sources of strength that could enable Japan to oppose the US action, "conduct amphibious forcible entry," to accomplish the ends, "establish a foothold on Okinawa," (step A.8.0). Recall from the discussion of perspectives above that when "enemy" centers of gravity are considered, it is efficacious to view the aims of the enemy as opposing the friendly aims, so that the analysis might yield those sources of strength most significant to the accomplishment of the friendly ends. These ends might be different from the actual aims held by the enemy force, which would be accounted for when the process is repeated from that perspective.

Therefore the operational "aim" of Japan for the purpose of this analysis was assumed to be the opposition of US operations to conduct amphibious forcible entry to establish a foothold on Okinawa during this phase. Again drawing from the UJTL (DOD 1999), two tasks accounted for the main actions that Japan could take to oppose the US in this phase: "interdict operational forces/targets (the US landing forces)," (step A.8.1.0) and "control operationally significant land area," (step A.8.1.1). The operationally significant land area in this case is the site of the landing beaches.

In considering the forces available to Japan to oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa, the overall operational force, referred to as Japanese Forces Okinawa, was considered. It was not capable,

however, of controlling the operationally significant land area in the vicinity of the beaches because of insufficient forces in the vicinity of the landing beaches (step A.9.0.1). It was found to have the capability to interdict the US landing forces, and so it was considered with regard to that action (step A.9.0). While the defeat of that capability would lead to US success in establishing a foothold on Okinawa, this capability was later localized to a subordinate force (step A.9.3.0), and thus this candidate is eliminated as a center of gravity in itself.

Japanese Air Forces (including Kamikaze) is a subordinate force grouping within TF51 Japanese Forces Okinawa that provided the capability to interdict US landing forces (step A.9.1.0). Japanese aircraft posed the most significant threat to forces on beaches and afloat. The defeat of this force would have directly enabled the US to establish a foothold on Okinawa (step A.9.2.0) and no further subordinate grouping of forces within Japanese Air Forces was found to be a more focused center of gravity (step A.9.1.1). Therefore this is a defensible center of gravity choice.

In considering the capabilities (besides military force) that might enable Japan to oppose US operations to conduct amphibious forcible entry, the capability to concentrate two divisions at the site of the main US landing was found to provide Japan the ability to concentrate forces in theater of operations to control landing beaches (step A.10.0.1). This candidate was considered a viable center of gravity choice because the defeat of this capability would prevent the Japanese control of the beaches. The elimination of this most immediate Japanese threat to the beaches would directly enable the US to establish a foothold on Okinawa.

As in the friendly modeling, enemy center-of-gravity determination also considered sources of strength that provided freedom of action (step A.11.0.0.1) or will to fight (step A.11.0.1.1). No such sources of strength were found that provide Japan the ability to conduct either of the operational actions under consideration that could oppose the US amphibious forcible entry to establish a foothold on Okinawa.

Ends and Ways of the Ground Operations Phase

The process of examining both friendly and enemy centers of gravity was then repeated for the ground operations phase (step G.3.0). Still conducting analysis from the US perspective, the operational aim of the US for this phase was identified as "seize Okinawa." The ways under consideration for the accomplishment of this end state was expressed using the UJTL task, "conduct offensive operations in theater (Okinawa)," (DOD 1999).

Friendly Centers of Gravity for the Ground Operations Phase

Potential friendly centers of gravity relative to this phase came from the sources of strength available to the US that could accomplish the action, "conduct offensive operations in Okinawa," to accomplish the aim, "seize Okinawa," (step G.4.0). Again beginning with forces that were capable of the operational action in question, the overall operational force, TF56 (Expeditionary Troops), was considered because it was the overall military force to be used by US during the assault on Okinawa phase and it was capable of offensive operations on Okinawa to seize the island (step G.5.0). Testing this candidate revealed that it was a viable center of gravity choice because its defeat would

have prevented the US from seizing Okinawa, since there would not be enough remaining forces with this capability to accomplish the aim, and no further subordinate grouping of forces within TF56 (Expeditionary Troops) was found to be a more focused center of gravity (step G.5.3).

Among the subordinate force groupings of TF56 (Expeditionary Troops), both III Amphibious Corps and XXIV Corps were considered capable of conducting offensive operations during the ground operations phase to seize Okinawa (step G.5.1), but the elimination of either corps would still leave sufficient force to carry on and win, albeit with greater difficulty (steps G.5.2.0-1). Therefore both candidates were eliminated.

The modeling again considered the capabilities (besides military force) available to the US, this time to conduct offensive operations to seize Okinawa in the ground operations phase, but none were identified (step G.6.0). Similarly, no sources of strength were found that provide the US either freedom of action or will to fight to conduct offensive operations to seize Okinawa (steps G.7.0.0-1).

Enemy Centers of Gravity for the Ground Operations Phase

Potential enemy centers of gravity for this phase came from the Japanese sources of strength that could enable Japan to oppose the US action, "conduct offensive operations to seize Okinawa," (step G.8.0). As in the previous phase, because the analysis was done from the US perspective, the aims of the enemy were assumed to be the direct opposition of the friendly aims, so that the analysis might yield those sources of strength most significant to the accomplishment of the friendly ends. In this example,

these ends are different from the actual aims held by the enemy force, which would be accounted for when the process is repeated from that perspective.

The operational aim of Japan for the purpose of this analysis was assumed to be opposing US operations to seize Okinawa during this phase. The UJTL task, "conduct defensive operations in theater," (DOD 1999) described the operational level action that Japan could take to oppose the US in this phase (step G.8.1).

In considering the forces available to Japan to oppose US operations to seize Okinawa, the overall operational force available to Japan in this phase was identified as the 32nd Army (step G.9.0). It was capable of conducting defensive operations in Okinawa to oppose the US operations, and the defeat of this force would certainly lead to US success. There were several major subordinate groupings within 32nd Army that could also be considered. At the time of the invasion, all forces were defending the southern portion of the island. Within that area, 62nd Division defended the central Shimajiri isthmus. South of the 62nd Division, 24th Division and 44th Independent Brigade defended the southernmost remainder of Okinawa. Both forces were capable of conducting defensive operations in their respective areas of operations (step G.9.1). Neither was found to be a viable alternative as center of gravity, however, because the elimination of either one of these forces does not appear to lead directly to the accomplishment of the US aim (steps G.9.2.0-1). All forces had to be defeated for the island to be seized. Therefore, the modeling reflects that the entire 32nd Army must be defeated, and so this overall force was chosen as a viable center of gravity (step G.9.3).

No center of gravity candidates were found among the capabilities (besides military force) available to Japan to oppose US operations to conduct offensive

operations to seize Okinawa (step G.10.0). In addition, no sources of strength were found that provided Japan either the freedom of action or the will to fight to oppose US offensive operations to seize Okinawa (steps G.11.0.0-1).

Table 1 summarizes the center of gravity candidates that were identified using the task reduction approach for the US perspective in the Okinawa campaign. It is important to emphasize here that this particular center of gravity analysis, although based on the discussion of doctrinal considerations presented earlier, is nevertheless only an example analysis of this scenario. The purpose of the example is to test the applicability of the task reduction paradigm to this problem based on an example. In principle, the approach should be sufficiently applicable to accommodate various opinions regarding the identification and evaluation of center of gravity candidates. To test that applicability, a general model was next derived from this example and tested on a new scenario.

Table 1. Summary of Center-Of-Gravity Candidates Considered Using Task Reduction, US Perspective, Okinawa Campaign

US	Japan
<u>Assault Phase</u>: TF51 (Joint Expeditionary Force) – eliminated **Main Landing Forces** – selected TF53 (Northern Attack Force) – eliminated TF55 (Southern Attack Force) – eliminated	<u>Opposing US Assault Phase</u>: Japanese Forces Okinawa – eliminated **Japanese Air Forces** – selected (including Kamikaze) The capability to **concentrate two divisions** at the site of the main US landing – selected
<u>Ground Phase</u>: **TF56 (Expeditionary Troops)** – selected III Amphibious Corps – eliminated XXIV Corps – eliminated	<u>Opposing US Ground Phase</u>: **32 Army** – selected 62 Div – eliminated 24 Div and 44 IMB – eliminated

The Derived General Model

In order for a learning agent to apply the logic of an example to a new case, an agent must derive generally-applicable rules. The general model presented here was derived based on the Okinawa modeling using the generalization procedures described in chapter 3. It represents the potential for such learning to take place. It contributes to the thesis question by answering the supporting question: Can center-of-gravity determination procedures be modeled for use by a computer-based agent? It also re-addresses the related question regarding generally applicable procedures for center-of-gravity determination, partially answered in literature review. While no existing procedure in the literature is immediately usable for this purpose, the model presented below provides evidence that such procedures can be discerned through analysis of a case study.

The general model is described below and illustrated at appendix A. All step numbers in the following description refer to the step numbers indicated in the appendix.

Scenario Type and Opposing Forces

Center-of-gravity determination must begin with a basic understanding of the scenario under consideration. Although the considerations are straightforward preliminary matters, an agent needs this sort of information to begin reasoning. Thus the generalized model accommodates the initial consideration of scenario type as exemplified in the Okinawa example. Success in reasoning about conventional scenarios might well lead to further development for stability and support operations. The first modeling step

(step 1) provided for this eventuality, distinguishing the conventional scenarios from the others, which are outside the scope of this work.

To generalize this step from the example, the scenario-specific information in modeling step *Okinawa 1.0* was identified and parameterized. This required the replacement of the scenario name, “Okinawa_1945,” with the parameter, *<Scenario Name>*. In addition, the necessity for multiple answers to the question regarding the opposing forces in the scenario was represented with the flow control symbol for multiple answers. The opponent name was also parameterized appropriately (e.g., “US_1945” was replaced with *<Opponent_1>*).

Friendly and Enemy Center-of-Gravity Determination From Multiple Perspectives

Modeling step 2 begins analysis from a particular opponent’s point of view. The first distinction made in this step is whether the opponent is a single-member or a multi-member force. Although the modeling in this thesis is done only for conflicts involving single-member forces, it is necessary to provide for later application to other types of opponents. This task was generalized by parameterizing and adding flow control as before. To begin with, all of the substitutions conducted in the previous step were made in the identical way here (i.e., *<Scenario Name>* and *<Opponent_1>* replaced “Okinawa_1945” and “US_1945” respectively).

In this step the modeling also determines whether distinct phases of the force’s operations should be considered for the purpose of center-of-gravity determination. These distinctions should not necessarily follow exactly the phasing used in actual plans. Phases here should be distinguished only where they might better inform center-of-

gravity determination, especially where there are major shifts in the organization or distribution of forces or changes in operational aims that might influence center of gravity selection. Thus while the example modeling in *Okinawa 2.0* yielded distinct phases, generalization recognized the possible alternative response, that there are no phases. This is represented with the flow control symbol representing a decision.

When phase distinctions are identified, this model allows an agent to consider centers of gravity relative to the ends, ways, and means that are unique to each phase. Generalization provided for any number of phases by adding the flow control symbol for multiple answers to represent each phase name. The phase name (e.g., "Assault on Okinawa") was parameterized as *<Phase Name>*. This allows all reasoning from this step forward to be repeated for any number of identified phases.

(From this point forward the detailed description of applying the generalization methodology is no longer provided. Parameterization and flow control continue as described in a consistent and straightforward manner.)

For each phase of the operation, the model next determines the force's aims and the ways under consideration (expressed as operational tasks) to accomplish those aims. As presented earlier in this chapter, these considerations, implicit in human reasoning, are made explicit to guide agent reasoning. Modeling step 3 directs that center-of-gravity determination be repeated in full for each aim and for each task under consideration to accomplish that aim. This allows for a thorough examination of all of the means that could emerge as centers of gravity. To keep the search focused, however, it is probably best that only the most significant and distinguishable aims and tasks be identified. For implementation, the number of aims and tasks identified in any circumstance depends in

large part on the level of detail provided by the expert teaching the agent. For each task under each aim, the modeling conducts separate analysis to determine friendly and enemy centers of gravity.

Friendly Centers of Gravity

Identifying and testing centers of gravity involves examining the sources of strength presented in the previous section, Considerations for Center-of-Gravity Determination. Thus for each opponent the model finds and tests candidate centers of gravity from among sources of strength identified in contemporary definitions: forces, capabilities, and other sources of strength that provide freedom of movement or will to fight. Modeling steps 4 through 7 guide the exploration of each source of potential friendly centers of gravity, beginning with step 4.

These sources are re-evaluated as many times as necessary to account for phases, operational aims, and the ways of accomplishing the aims within those phases (steps 2 and 3 of the model). This provides a thorough examination of the scenario, but it is not necessarily the case that this exhaustive reasoning process should find centers of gravity related to each task, aim, or even phase. It might well be the case that no sources of strength present themselves in many of these circumstances. The main determinant of how conservatively or liberally potential centers of gravity are found is the preference of the modeler. When this sort of model is applied in Disciple, this behavior conforms to the preferences of the expert teaching the agent.

Forces That Provide Physical Strength

Forces are the most common source of operational center of gravity. Initially it is tempting to look at all forces and to evaluate them all as potential centers of gravity. One problem with this approach is that there are too many ways to aggregate forces, including unit groupings from the order of battle as well as incidental kinds of groupings such as physical proximity. Generalizing the Okinawa model revealed a more efficient way to address forces with regard to the primary concern--the capability to accomplish the identified ends with the ways under consideration (i.e., operational tasks that accomplish operational aims as identified in modeling step 3. The resulting approach is to start with the tasks and aims and identify only forces that provide the capability to conduct such a task to accomplish the aims in question. An agent could draw from its knowledge base to determine what forces fit this description for a scenario. Some of the required knowledge would be present in the agent's general ontology as a sort of latent knowledge about what kinds of forces provide what capabilities. Capabilities could be drawn from the UJTL. Additional knowledge, especially that which is scenario specific, would be added by the expert instructing the agent.

Modeling step 5.0 begins the examination of forces with the overall operational force employed by the opponent whose perspective is being analyzed. Provided it is capable of the task at hand, it is automatically a candidate friendly center of gravity. Reasoning about forces continues with step 5.1, wherein increasingly more subordinate forces or groupings of forces (that are also capable of the task) are identified and tested. The overall force stands to be chosen as a center of gravity based simply on this capability, but only if a more focused subordinate force does not appear to be a center of

gravity based on the same capability. The reasoning behind this process of elimination is examined in modeling step 5.3.

With this first mention of “candidate” centers of gravity, it is necessary to emphasize that a candidate center of gravity is simply that--a source of strength that has the potential to be chosen as a center of gravity provided that it passes some additional tests. The explicit identification of such candidates helps clarify the reasoning process and, when implemented in an agent, leads to more articulate explanations of what was considered and what was chosen. The term “candidate” is used in this sense for the remainder of this analysis.

Determining the forces that matter to this analysis depends in part on the scenario description. The order of battle for operational forces provides a starting point, but other groupings relevant to this analysis can also be identified ahead of time in scenario elicitation. These include forces that are geographically close to one another, those that have a common capability or purpose, or ones that share some other unique characteristic in common (e.g., strong loyalty to a leader or cause). Example modeling demonstrated how the identification of such groupings can lead to center of gravity candidates that are not identifiable strictly from an order of battle. It is also the case that task organization and other groupings can shift during a campaign. The conduct of this analysis relative to the phasing of the operation and flexible force groupings provides for this common occurrence.

The search for more focused choices among forces that provide the capability in question is a recursive process whereby the subgroups of each candidate are further examined as in step 5.1 until no further candidates are found. Each such subgroup is

automatically a candidate if it is known to be capable of the action in question (implicit in the task and question in step 5.1).

The test of candidate forces is shown in modeling step 5.2. The reasoning in this step is to prefer the most focused force in a particular structure that provides the capability to win and without which the operation would likely fail. Each new candidate is sent back to step 5.1 in the search for more focused candidates. This duplicates the insight reflected in the analysis of authors who promote this as an evaluation criterion for centers of gravity (Schneider and Izzo 1987; Izzo 1988; Keppler 1995; Giles and Galvan 1996). The test also requires that, as with the overall operational force, a force be selected as a center of gravity only if a more focused one further down is not found.

Step 5.3 of the evaluation of forces completes the examination of forces by determining whether a more focused choice of force can be advanced as a center of gravity based on this capability. Recall that due to modeling steps 2 through 4, forces are revisited from the beginning as many times as necessary to account for phases, operational aims, and the ways of accomplishing the aims within those phases.

Capabilities That Provide Physical Strength

Although operational centers of gravity are most often found among forces, in some circumstances a characteristic of the force is the foundation of operational capability. Thus a second major kind of strength provided for in the doctrinal definition and hence this modeling is a capability from which a force derives its strength. Modeling step 6.0 considers capabilities besides military force as sources of strength. The reasoning then identifies the means that provide that capability (e.g., force, weapon, or

system identified in scenario elicitation) as candidate centers of gravity. Step 6.1 continues by testing the means of the capability again using the contra positive reasoning similar to that in step 5.2, selecting those means without which the operation could fail.

Because centers of gravity are found among the means of the operation, they should be the doers of the action, or ways, that can accomplish the operational aim, or ends. Thus centers of gravity inspired by important capabilities often (but not necessarily) turn out to be the forces that provide those capabilities. Finding such centers of gravity based on capabilities, however, might lead to units or special groupings of forces not otherwise evaluated when looking strictly at forces capable of operational tasks.

Sources of Strength that Provide Freedom of Action or Will to Fight

Doctrine allows that some centers of gravity provide the means to win by maintaining a force's freedom of action or will to fight. As with the modeling of force characteristics above, the exploration of such sources starts by looking for capabilities that provide freedom of action or will to fight, and continues by identifying the sources of those capabilities and testing their criticality (modeling step 7.0). The logic for determining the sources of freedom of action and the logic for determining the sources of will to fight are essentially the same. Therefore modeling steps 7.0 to 7.2 accommodate the questions about both of these potential sources of strength.

If ways can be identified in step 7.0 that provide the relevant strength in a significant way, then the next step is to determine the sources of that strength in step 7.1. That would be the source of the action that could potentially bring success. Testing the

criticality of that source to the success of the operation in step 7.2 is a matter of determining whether the operational aim is at stake without the freedom of action or the will to fight provided by that source.

Enemy Centers of Gravity

Enemy center of gravity modeling closely resembles friendly modeling. Key distinctions for enemy center-of-gravity determination are that this is still done relative to the "friendly" perspective. That is to say that enemy centers of gravity are those enemy strengths which, if defeated, most directly lead to the accomplishment of friendly ends. Therefore, analysis is still being done relative to "friendly" phasing, and the enemy aims are assumed to be the opposition of the friendly aims in order to find those enemy centers of gravity most relevant to accomplishing those ends. Enemy actions that can accomplish that assumed aim are considered as the ways that constrain and guide the search. Centers of gravity are again sought among forces, capabilities, and sources of strength that provide freedom of action and will to fight. The testing of candidates for viability differs in that the modeling is generally seeking sources of strength whose defeat would directly lead to the success of the friendly operation. The remainder of the generalized model otherwise requires no further explanation.

Applying the Model to Analyze a New Scenario

The application of task reduction approach to the Okinawa campaign demonstrates how a rigorous approach to operational center-of-gravity determination can be described to an agent for one example. The abstraction of that example into a general

model not only demonstrates how a computer can learn from the example, but also provides a procedure for rigorously applying the principles gleaned from the first example to a second one. This illustrates the potential for an agent to learn from an example and perform independent problem solving on subsequent cases. Analysis of the Panama campaign using the derived general model tests whether this model provides a basis for agent development in that way.

Application to a Second Case: Panama

This section presents the results of applying the generalized model for center-of-gravity determination to a second historical scenario, Operation Just Cause in Panama. The resulting new model, generated based on the procedure specified by the general model, addresses the supporting research question, Can modeling performed for one state versus state scenario apply to a second scenario that involves a state versus state conflict? An overview of the results of applying the model is presented as a guide to reading and understanding the complete task reduction modeling for the scenario as found at appendix C.

Brief Description of the Panama Campaign

Operation Just Cause, the US invasion of Panama in 1989, was a response to the deterioration of the legitimacy of the Panamanian government under Manuel Noriega and the consequent threat to US interests in that country, including the protection of US lives and the security of the Panama Canal. US-Panamanian relations had gone especially bad in 1987-1988 with increased corruption and instability in the military-controlled

government under Noriega. Contingency planning for US intervention began as early as February 1988. On 15 December 1989, Noriega and the Panama National Assembly announced that a state of war existed between Panama and the US, and Panamanian Defense Force (PDF) aggression against US citizens increased dramatically. On 20 December 1989, US forces commenced offensive operations in Panama, doubling the roughly 13,000 US troops in Panama to a total strength of over 27,000, with a primary operational objective of neutralizing the PDF. Airborne and special operations forces conducted multiple, simultaneous attacks throughout Panama against key PDF units, command and control nodes, and transportation nodes, and conducted defensive operations to protect US lives and the Panama Canal. US operational objectives were achieved quickly and with relatively light losses. Noriega finally surrendered to US forces on 3 January 1990.

The analysis presented below describes the application of the general model to this campaign. The content of the analysis is based on a detailed case study obtained from the USAWC Warfighting Studies Program, *Operation Just Cause: Panama 1989* (USAWC 2001c) and the Joint History Office monograph, *Operation Just Cause: The Planning and Execution of Joint Operations in Panama February 1988–January 1990* (Cole 1995). The reader is referred to those sources for more detail.

<u>US Perspective, Ends, and Ways in Panama</u>

The analysis considered both friendly and enemy centers of gravity from the perspective of the US forces in this campaign (step 2.0). A “friendly” center of gravity is a US center of gravity to be protected, and an “enemy” center of gravity is a Panamanian

center of gravity to be defeated. In the interest of space, the analysis is not repeated from the Panamanian perspective, which would follow the identical pattern demonstrated here. Because no phases are distinguished for the purpose of center-of-gravity determination, analysis was conducted once for the overall campaign.

As specified in the general model, centers of gravity were determined from the means that could achieve or oppose the accomplishment of the US ends. The operational aim of the US in this scenario was, “disarm and dismantle the PDF,” (step 3.0). The ways under consideration for the accomplishment of this end state were expressed using the UJTL task, “conduct offensive operations in theater,” (DOD 1999).

Friendly Centers of Gravity

Potential friendly centers of gravity came from the sources of strength available to the US that could conduct offensive operations in Panama to disarm and dismantle the PDF (step 4.0). The analysis first considered the forces available to US (step 5.0). The overall operational force, JTF SOUTH, was capable of performing this action. Although its defeat would have prevented the US from accomplishing the stated ends, a subordinate grouping of forces within JTF SOUTH was later found to be a more focused center of gravity capable of this action (step 5.1.0). This more focused choice is referred to as the “assault forces” (those forces conducting forced entry by airborne assault). Those forces provided sufficient capability to conduct offensive operations to win for the US, and their defeat would have prevented the accomplishment of US aims because the remaining US forces in country cannot could not offensive operations with sufficient speed and surprise to accomplish the aim (step 5.2.0). No further subordinate grouping of forces within

assault forces was found to be a more focused center of gravity, since the PDF objectives were too dispersed for any subordinate force to adequately accomplish the overall purpose (step 5.1.1).

Another grouping of forces within JTF SOUTH that was considered but rejected was the balance of the US forces that were already in country prior to the operation (step 5.2.1). The in-country forces were capable of conducting offensive operations in Panama to disarm and dismantle the PDF, but their defeat would not likely have prevented US success. The assault forces would still have had adequate combat power to conduct offensive operations with the speed and surprise necessary to accomplish the aim, and so the in-country forces were discounted as a center of gravity.

Analysis informed by the general model also considered capabilities (besides military force) available to the US (step 6.0), as well as sources of strength that provide the freedom of action or will to fight to the US (steps 7.0.0-1). No friendly candidates of these types were found.

Enemy Centers of Gravity

Potential enemy centers of gravity came from Panama's sources of strength that could oppose US offensive operations to disarm and dismantle the PDF (step 8.0). Because this analysis was done from the US perspective, "enemy" centers of gravity were considered those Panamanian strengths that, if defeated, would lead to US victory. Therefore, the operational aim of Panama was taken as opposing US operations to conduct offensive operations to disarm and dismantle the PDF. Again drawing from the

UJTL (DOD 1999), the analysis used the task, "conduct defensive operations in theater," to describe the operational action that Panama could take to oppose the US.

The overall military force available to Panama during the operation was the PDF (step 9.0). It was capable of conducting defensive operations in Panama. The defeat of the PDF's capability to conduct defensive operations would have (by definition) enabled the US to disarm and dismantle the PDF, and there would not have been any remaining forces with this capability to accomplish the aim. Furthermore, no further subordinate grouping of forces within the PDF was found to be a more focused center of gravity for this purpose, since all of the subordinate units were too small and dispersed to substantially oppose the US operation on their own (step 9.1).

The consideration of capabilities (besides military force) that provide Panama the ability to conduct defensive operations to oppose the US attack yielded no enemy center of gravity candidates (step 10.0). However, candidates were found among sources of strength that provide both freedom of action and will to fight. It was determined that freedom of action was maintained by the centralized command and control of the dispersed PDF units, conducted through the Commandancia (step 11.0.0). The PDF units stationed there, referred to in the analysis as "Commandancia Forces," protected this ability, and so were the proximate source of strength and center of gravity candidate. This force was found to be a defensible choice for enemy center of gravity because the defeat of its protection of the Commandancia would have led to the elimination of the centralized command and control of the PDF. The resulting loss of centralized control would have enabled the US to disarm and dismantle the isolated and ineffective PDF units, thus accomplishing the ends.

Will to fight yielded another candidate (step 11.0.1). The will of the PDF to fight against the US was strengthened by units particularly loyal to Noriega. The PDF force at Rio Hato (6th and 7th Rifle Companies) was a loyal unit that maintained Noriega's control over the PDF, and thus maintained the PDF's overall will to fight. This force was found to be a viable center of gravity candidate because the loss of Noriega's control over the most loyal and capable elements of the PDF would have exposed Noriega to capture and would have caused the remainder of the PDF to become demoralized. The harm done to the PDF's will to fight against US operations would have directly enabled the US to disarm and dismantle the PDF.

In summary, the following centers of gravity were identified by applying the general model to the US perspective in the Panama campaign (table 2). It is again important to emphasize that this particular center of gravity analysis is only an example analysis of this scenario. The purpose of the example is to test the applicability of the derived model to a new scenario, not to promote a particular opinion regarding center of gravity selection for this case. In addition, although three potential enemy centers of were identified in the analysis, this is interpreted as recognizing that cogent arguments exist for believing any one of them to be a center of gravity, and not necessarily that they all must be recognized at once as centers of gravity.

Table 2. Summary of Center-Of-Gravity Candidates Considered Using Task Reduction, US Perspective, Panama Campaign

US	Panama
JTF South – eliminated **Assault Forces** – viable In Country Forces – eliminated	**PDF** – viable **Commandancia Forces** – viable **6th and 7th Rifle Companies** – viable

Findings from Modeling

The general task reduction model derived from the Okinawa study enabled an analysis of the Panama scenario without altering the existing logic. This is demonstrated in two ways. First, of the 24 major steps in the general model (including sub steps), each one was used successfully for the Panama study. These steps generated 46 separate reasoning tasks, each of which was well formed, resulting in successful alignment between the test case and the general model (and by extension, between the modeling example and the test case). Each of the 46 generated tasks for Panama was productively answered by either a conclusion or further task decomposition without any modification. This indicates that the model is generally applicable and that a Disciple agent would make good use of the modeling for example-based learning (Tecuci 1998, 115).

In addition, the modeling also accommodated reasoning inspired by the second scenario that was not exemplified in the first, providing evidence that the method is sufficiently adaptable that an agent could apply the procedure to new scenarios and refine its learning based on new examples. There were two sources of new reasoning in the test scenario (Panama) that were not directly exemplified in the example scenario (Okinawa). In Okinawa, no examples were provided for the positive identification of centers of gravity from the sources of strength that provide either freedom of action or will to fight. This was necessary for Panama, however, for both sources. In one case, Commandancia Forces were identified as a potential center of gravity that provided the PDF its freedom of action by virtue of the protection of the facility for centralized command and control. This required new task decomposition that resulted in four new tasks, including two new

conclusions. In the other case, the 6th and 7th Rifle Companies at Rio Hato were identified as a potential center of gravity that provided the PDF its will to fight by virtue its contribution to Noriega's control over the PDF. The new task decomposition that resulted from this also generated four new tasks, including two new conclusions. Each of these tasks was successfully instantiated. No inconsistencies were introduced elsewhere in the modeling as a result of these additions, resulting in successful adaptation to the new example. This exhibits the kind of model adaptation that an agent must perform in order to learn from new examples, and demonstrates that the general model is sufficiently adaptable for such use. This is important because an agent increases its proficiency by adapting learned procedures based on new examples. This works best when the adaptations do not create inconsistencies elsewhere in the logic.

In conclusion, the model's applicability and adaptability in analyzing the new case demonstrated the technical soundness of the model and its suitability for agent use. The application of task reduction modeling to two historical scenarios that exemplify state versus state conventional war answered the secondary research question, Can a problem-solving method for center-of-gravity determination be formalized for use by a computer-based agent, as well as the secondary question, Will the modeling apply to multiple scenarios? The evaluation of results using subject-matter experts, described next, separately tests the validity of the logic.

Results of Expert Evaluation

Expert evaluation of modeling output tested the credibility of the results. Results were deemed credible to the extent that independent evaluators agreed with the candidate

centers of gravity considered, whether they agreed with the selection and rejection of candidates, and whether they agreed with the explanations (generated from the modeling) for those decisions. The methodology for conducting expert evaluation was presented in chapter 3. The evaluation instruments used for collecting the data are at appendix D. The data collected from the evaluations is in appendix E. The conclusions drawn from that data are presented below.

Overall, 23 different evaluators drawn from the faculties of the USAWC (Department of Military Strategy, Planning, and Operations) and CGSC (Department of Joint Military Operations) participated in the evaluation. Of these respondents, 15 met the screening criteria for expertise in the concept of center of gravity and familiarity with the campaigns. Each of the 15 qualified evaluators completed the instruments for both the Okinawa example and the Panama example, resulting in a total of 30 evaluations. On average, evaluators had 28 years of military experience (ranging from 20 to 33) and 5.2 years of experience teaching the center of gravity concept at the staff college or senior service college level (ranging from 1 to 14, median=4).

The results show that experts overall agreed with the conclusions determined in the task reduction models (table 6 and figure 6). Section IV on each evaluation, "Overall Center of Gravity Analysis," asked the evaluators to characterize the analysis taken as a whole. Results from the responses to these questions indicate that the results of the modeling are generally acceptable, with 80 percent agreeing or strongly agreeing that overall the right center of gravity candidates were considered and 67 percent agreeing or strongly agreeing that overall the right center of gravity selections were chosen from among those candidates. (From this point, "agree" and "strongly agree" are considered

together in the remaining analysis as agreement in general.) This exceeds the criterion of over 50 percent agreement established in chapter 3, and suggests that overall the task reduction modeling is capable of reaching credible conclusions. The responses to section IV questions also show that experts generally accepted the rationale used to analyze centers of gravity. Among respondents, 83 percent agreed that overall centers of gravity were chosen for valid reasons and 80 percent agreed that overall centers of gravity were eliminated for valid reasons. All of these results indicate that task reduction can be applied to produce generally acceptable results for operational center-of-gravity determination.

Beyond the general evaluation of the results as measured by responses to section IV, a detailed examination of the responses to the individual determinations in section III reveals the aspects of this approach that were accepted to greater or lesser extent (table 7 and figure 7). Section III of each survey (appendix D) gave evaluators the opportunity to agree or disagree with the substantiation or elimination of each candidate as a viable center of gravity and the rationale for doing so. These individual evaluations provided more detailed insight into the credibility of results. Where candidates were selected as viable centers of gravity, 74 percent of the evaluators agreed with the statement, “I agree that this is a valid center of gravity for this scenario,” (table 7, *Selection of a COG, all sources*) and 73 percent agreed that, “The rationale presented for choosing this center of gravity is valid,” (table 7, *Rationale for choosing a candidate as a COG*). Where candidates were eliminated as centers of gravity, 80 percent of the evaluators agreed with the elimination (table 7, *Elimination of a candidate as a COG*) and 71 percent agreed

with the accompanying rationale (table 7, *Rationale for eliminating a candidate as a COG*).

A closer look at expert concurrence with center of gravity selections reveals that experts agreed most often with selections that were made from among *forces* that provide the physical strength to achieve the aim at hand. Where forces were identified as either a friendly or an enemy center of gravity candidate and subsequently accepted as viable, 88 percent of the evaluators agreed or strongly agreed with the statement, “This is a valid center of gravity for this scenario,” (table 7, *Selection of a COG from among forces*).

In contrast, 53 percent of evaluators failed to agree with selections of centers of gravity from among capabilities and other sources of strength that provide freedom of action or will to fight (table 7, *Selection of a COG from capabilities or other sources of strength*). This is the one category in which agreement did not exceed the 50 percent threshold established in chapter 3. This result might suggest that the modeling logic that follows from steps 5.0 and 9.0 is more reliable than the logic that follows from steps 6.0, 7.0, 10.0, and 11.0. An alternative interpretation is that the two scenarios did not adequately or correctly exemplify the latter sources of operational centers of gravity. To test this possibility, additional examples should be modeled to clarify the results. Because these interpretations are not mutually exclusive, both provide an opportunity for improving the model.

Although the results of this evaluation suggest that experts agree with the determinations and rationale, the minority of cases indicating lack of agreement (including *neutral* answers) can still offer useful insight. Comments included in such

cases, suggesting other possible candidates, reveal two recurring types of disagreements. These sources of disagreement are discussed below.

In one sort of disagreement experts submitted candidates that the model's logic as specified could have considered, but were not included in the example analysis. For the Okinawa scenario, several experts made the case for considering the US Fleet, amphibious support forces, and similar candidates, because such candidates provided the overall force the freedom of action necessary to conduct decisive operations. Similarly, several experts suggested that in the Panama scenario, strategic lift provided the US freedom of action to conduct the assault, without which the force could not have won. The model's logic could accommodate such candidates provided that the modeler represents such sources of strength as capable of performing the operational actions at hand. Such sources were omitted in the example due to the implicit judgment that candidates such as these are key enablers (e.g., supporters, transporters) but not a primary doer of the operational action that accomplishes the aim. (E.g., the amphibious support force does not itself perform the action, "conduct amphibious forcible entry to establish a foothold on Okinawa.") Such examples should be examined explicitly in future modeling, and the logic for accepting or rejecting them made clear. One caution to address in modeling such examples is that the logical extension of such selections might lead towards the indiscriminate selection of modes of transportation, lines of communication, and other enablers as centers of gravity (i.e., if the force cannot get there the force cannot win). Such candidates are attractive when their defeat is believed to "create a cascading, deteriorating effect on morale, cohesion, and will to fight that prevents [an] enemy from achieving his aims and allows the achievement of [friendly

aims]" (Mendel and Tooke 1993). However this challenges the view (reviewed earlier) that despite their great value, such "Achilles' heels" are not centers of gravity, but instead indicate decisive points and other features that help identify the means that they enable, which are the preferable center of gravity candidates (Schneider and Izzo 1987; Izzo 1988; Keppler 1995; Giles and Galvin 1996). As currently construed, the model presented in this thesis can accommodate either preference for recognizing and evaluating candidates. If desired, the modeling might be revised to prefer one approach or the other.

The second major type of disagreement to examine involves candidates nominated by experts that the model cannot currently accommodate. These differences reveal fundamental divergence of opinion regarding operational center of gravity. Several experts suggested Japanese culture (or variations of this such as "fatalism" and "Bushido spirit") as an enemy candidate for Okinawa that gave the Japanese force the ability to resist as it did. On the friendly side in Okinawa, air superiority was suggested as primary for the US to win. In the Panama scenario, the ability to hit many targets simultaneously was offered as a US candidate, and Noriega's ability to command and control the PDF was recommended on the Panama side. In both scenarios, leadership candidates were suggested--Noriega for Panama and the commander of the 67th Division in Japan for the unique contribution each made to determining the course of action of the respective force. None of these candidates can fairly be produced using the logic of the current model. It is a matter of conjecture whether, if these candidates had been generated by the model, objections would have been raised by other evaluators. This

could be tested with further modeling and similar evaluations. For agent implementation, an extended model would be necessary to produce this broader range of candidates.

Findings from Expert Evaluation

The results of expert evaluation provide an answer to the secondary research question, Will the modeling produce credible results? As shown in appendix E and as discussed in the previous section, most of the expert evaluators agreed with most of the analysis produced by the model. There was a high acceptance of the overall performance of the model (table 6 and figure 6). There was also agreement over specific determinations, as evidenced by the selection of centers of gravity that were consistent with the choices of 74 percent of the experts and elimination of candidates consistent with the choices of 80 percent. In addition, the high acceptance rate of the reasoning behind candidates accepted and rejected also demonstrated that the logic of the modeling represented valid reasoning about centers of gravity (table 7 and figure 7).

Notwithstanding the few exceptions discussed, credible candidates were identified, and the logic used to accept or reject them was sound. This agreement was strongest regarding the consideration of forces, while the most significant disagreement arose over consideration of candidates among sources of strength other than forces. Given the wide variation of beliefs regarding center of gravity, this is not a total surprise. To the extent that these disagreements stem from substantially different approaches to operational center of gravity (and not the example's failure to recognize something otherwise provided for in the model), this reflects the implicit bias in the model regarding definition. The model reflects a conservative view of the relationship between the center

of gravity concept, the ends, ways, and means of operational design, and related concepts. It is conjectured that if the examples were to include a wider range of contentious candidates, disagreement might still have existed where candidates were not found; and in addition, greater disagreement might have existed where candidates were found that violated the more conservative notion of the concept for other evaluators. Thus it cannot be determined without further development whether the model can be modified to produce results acceptable to an even greater proportion of experts.

An agent developed based on any model such as this one would consequently also reflect its inherent bias. The strength of intelligent agent development is that modeling is not done to this degree of formality as a prerequisite for development. Instead, models such as these are learned internally by the agent as a result of exposure to examples and the analysis of the expert teaching the agent. An agent taught based on the examples in this thesis will reflect biases such as the ones identified here. In principle, an agent could accommodate alternative views of centers of gravity if furnished with the appropriate examples. Thus any number of agents could simultaneously be developed and used, each of which would mimic the preferences of the experts who taught it.

Summary

This chapter has presented all of the results and findings obtained by developing and evaluating a computer model for determining operational centers of gravity. First the considerations gleaned from literature review and historical cases were presented. Then those considerations were applied in analyzing an historical scenario, and a general model was derived from that example. The resulting model indicated that logic for

selecting the operational center of gravity can be discovered through the application of the task reduction paradigm. The general model was then applied to a new scenario to test its validity and its suitability for developing Disciple agents to support the same task. The successful application to a new scenario demonstrated that the model is suitable to Disciple agent development. In addition, the credibility of the conclusions and explanations produced by the model was judged using expert evaluations. The results of expert evaluation suggest that on the whole the model produced credible results and represented an acceptable approach to determining operational centers of gravity. Chapter 5, "Conclusions and Recommendations," presents the overall conclusions of the research by revisiting the thesis question in relation to the findings presented here. Chapter 5 also makes observations regarding prospects for furthering this work, the application of the model for the development of agents, and areas for related research.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

The results of this research indicate that computers can be taught to conduct center-of-gravity determination using current learning agent technology. A formal methodology has been derived based on task reduction modeling of historical examples and informed by a survey of doctrinal and academic thinking about center of gravity. Analysis demonstrates that the resulting model is suitable for developing agent support of this complex task, and expert evaluation indicates that such an approach is capable of producing credible results. The first part of this chapter reviews those results to answer the research questions that support the thesis question.

While answers to the immediate research questions are promising, the model presented here is by no means complete. Therefore, following the conclusions, the remainder of the chapter suggests opportunities to further this work in order to improve the result. Given that the model has potential as a basis for agent development, this also includes recommendations regarding prototype agent development and potential application. Finally, areas for further research are explored.

Conclusions

The modeling and analysis presented in this thesis suggest that the center-of-gravity-determination process is amenable to agent development. This conclusion is supported by the findings for the following secondary research questions, which were examined throughout the thesis:

1. Can a problem-solving method for center-of-gravity determination be formalized for use by a computer-based agent?
2. Will the modeling apply to multiple scenarios?
3. Will the modeling produce credible results?

The methodology for addressing the primary and secondary research questions was presented in chapter 3 and the results of analysis are presented in detail in chapter 4. The questions were addressed through a review of literature, task reduction modeling of historical cases, and evaluation of results. The results of that analysis are summarized for each question in turn in the sections that follow.

Determining a Problem-Solving Method for Agent Use

The determination of a formal problem-solving method for operational center-of-gravity determination was further refined into three more subordinate questions. One question concerned the relevant concepts that need to be in a computer's knowledge base in order to conduct center-of-gravity determination. A review of doctrine and literature revealed important relationships between the center of gravity and the ends, ways, and means of operational art. The guiding principles for modeling are: (1) ends, ways, and means are relative to each opponent's perspective; (2) centers of gravity are found among the means of the operation; (3) centers of gravity must be capable of accomplishing the ends of the operation; (4) the ways available for the operation constrain the means that should be considered; (5) centers of gravity are the means that matter most. These principles are key to constraining agent behavior, and thus guided the modeling and provided doctrinal relevance.

A second subordinate question related to determination of a formal problem-solving method concerned the existence of a previously determined method that could be adapted to the purpose of agent development. No existing procedure was found. Instead, the model presented in this thesis demonstrates that such a procedure can be determined through analysis of examples. Thus the answer to a third subordinate question, regarding the feasibility of modeling center-of-gravity determination procedures for use by a computer-based agent, makes up for this lack of existing procedures. Using the task reduction problem-solving method used by agents considered in this study, center-of-gravity analysis was modeled for the Okinawa campaign. Using that example as a basis, a general model was then derived by completing the logic and parameterizing scenario-specific information. In principle, such a general model should provide a formal method that is appropriate for use in a generally applicable instructable agent. The remaining two secondary questions address that applicability.

Application of the Modeling to Scenarios

The key determinant of the usefulness of a model is its applicability to a new scenario. Further research questions in support of this concern the application of the model to the chosen historical scenarios--ones that exemplify conventional war between states. Once derived from the first such conflict, Okinawa, the general model was applied to a second one, the Panama scenario. This demonstrates that the modeling conducted for one state-versus-state scenario could adapt successfully to a second similar scenario. This adaptability is supported by observing that the logic of the original example is essentially preserved when applied to the new example. All tasks generated

for the new example were productively answered either by a conclusion or by further task decomposition, without any modification to the original logic in the general model. In addition, the general model also accommodated reasoning inspired by the second scenario that was not exemplified in the first. All new tasks of this sort were successfully generated in the second scenario, demonstrating the kind of model adaptation that an agent must perform in order to learn from new examples. This indicates that the method is sufficiently adaptable that an agent could apply this procedure to new scenarios and refine its learning based on new examples. This is important because an agent increases its proficiency by adapting learned procedures based on new examples.

Credibility of Results

In addition to being sufficiently adaptable for agent use, the model also leads to determinations that correspond to the analysis of a significant majority of the subject-matter experts consulted in this research. The credibility of the model was measured using expert evaluation performed by selected faculty of the USAWC and CGSC. Expert evaluation showed that the modeling led to centers of gravity about the selected case studies that were consistent with the choices of experts. This is evidenced most strongly by the general agreement among evaluators with the center of gravity selections in both the Okinawa and Panama campaigns, and the general agreement among evaluators with the overall credibility of the model's selections and rationale. This demonstrates the efficacy of the agent learning style presented, as evidenced by the acceptability of the model's results. In addition, the logic of the modeling appears to represent a valid reasoning process for determining operational centers of gravity. This is evidenced again

by general agreement among evaluators with the *rationale* given for eliminating and choosing selected centers of gravity. These additional results indicate strongly that the model follows a valid line of reasoning. In sum, an agent that uses this model as a basis for its reasoning could be expected to produce credible determinations using task decomposition and offer coherent and plausible explanations for its reasoning.

Overall Result

The results of all three secondary questions--the determination of the problem-solving method, the application of that method to a new example, and the credibility of the results obtained with that method--all combine to answer the primary research question: Can computers be taught to conduct center-of-gravity determination using current learning agent technology? The answer is a qualified yes, insofar as these results anticipate the efficacy of actual agent construction. The methods and analysis presented in this thesis appear to provide a valid basis for such development. However, the model developed here represents at best a proof of concept demonstrating the applicability of the approach to the problem. It is not a conclusive statement regarding operational centers of gravity. Rather, it provides a methodology that is sufficiently formal for agent development and is also capable of producing realistic results. Recommendations for the model's application toward agent development is considered next, followed by a discussion of broader opportunities for further research.

Recommendations

The apparent applicability of agents to this domain suggests that this work should carry on. In the near term, the results presented here can be improved through refinements to the results using essentially the same methodology followed here. Recommendations for such immediate use are presented in this section. The continued improvement of the current results include model refinement and application to additional scenarios. The following section then considers the longer range implication of this work for future application.

Although the initial results from modeling are promising, opportunities for improvement were identified in the analysis. The most obvious place to start is with the deficiencies identified by expert evaluators. The consideration of capabilities and sources of strength that provide freedom of action and will to fight should be revised first. Modeling steps 6.0, 7.0, 10.0, and 11.0 should be extended or remodeled to reflect the suggestions made by evaluators. Such further development should bring those results up to the quality of the overall results. At that point, the overall model should be examined and refined with the aim of increasing the acceptance of the results by experts.

It may be possible to make the model produce answers that are validated by an even greater proportion of experts. The approach to this may lie not only in making modifications to the logic, but also in adjusting the phrasing of tasks in such a way that the rationale for decisions is more clearly communicated in the explanations that are enabled. Once the areas for improvement outlined in the preceding paragraph are addressed, expert evaluations should be repeated to verify the results. These evaluations should again measure credibility as in this thesis, and should specifically verify

improvement of both the model's logic (for problem-solving accuracy) and phrasing used in task decomposition (to enable better articulation of explanations). A worthy goal would be to raise the current 70-80 percent acceptability ratings to within the 80-90 percent range.

The model might also be modified with an eye toward accommodating a range of conflicting views of center of gravity. If desired, an agent could be intended to recognize a variety of typical preferences and react accordingly. An agent designed to recognize and react to such differences, rather than adhere to a strict construal of a particular view, could provide a more adaptable personal assistant or a basis for educational application. In this approach, alternative modeling approaches could be simultaneously developed, tested, and compared.

The current results can be further improved by the analysis of additional examples. Two historical examples is the minimal basis needed to derive a model and demonstrate applicability. The model should now be subjected to additional scenarios to inform the improvements suggested, and to identify additional prospects for fine tuning. At first, additional historical cases should be selected from among those similar to the development cases used here. These would ideally be further examples of conventional warfare between single-member forces (e.g., states). This provides a basis to refine performance within a narrow band of competence before branching out to more diverse examples. At the appropriate time, variations should then be introduced to expand the usefulness of the model. Such variations should involve a greater number of operational ends and utilize a broader range of operational ways. Scenarios involving multi-member alliances should also be modeled to determine how such situations complicate analysis.

At the extreme end of variation, military operations other than war could eventually be considered. All of these immediate refinements provide an improved basis for the application of this work in further research. Such opportunities are presented next.

Areas for Further Research

Beyond the immediate continuation of this work, there are several opportunities to apply these results in further research. This section makes suggestions for the development of prototype agents. Their potential application is also considered, as well as the integration of this work with related research being conducted at the strategic level.

This modeling should be used as a basis for the development of working agents. The model developed for this thesis is immediately applicable to Disciple learning agent development, and much of the knowledge required for implementation has been identified herein. As presented in the section on the target technology (chapter 3), this development relies on the decomposition of complex tasks into smaller and smaller component tasks and relies upon mixed-initiative problem solving on examples involving the agent and the teacher. Therefore a prototype can be developed rapidly by taking advantage of the model and the formalized examples.

Agent development would follow the agent development phases discussed in chapter 3. The first phase, scenario specification, requires the identification of the knowledge needed for problem solving. Much of this knowledge can be discerned from the considerations for operational center-of-gravity determination presented in chapter 4. Knowledge engineers should first specify an initial general ontology based on those considerations. This is a matter of adding new concepts to an existing ontology. In

addition, scenario elicitation scripts can be defined for each new concept to enable experts teaching the agent to furnish the scenario-specific inputs for historical examples. In the next phase, domain modeling, historical scenarios are provided to the agent using task reduction. The model and formalized examples presented here will directly inform this step, enabling the rapid modeling of both the Okinawa and Panama examples. In the remaining phases, rule learning and rule refinement enables the agent to acquire general problem-solving procedures based on the task reduction identified in the examples.

Although the examples presented in this thesis are fairly complete for the sake of illustration and analysis, only representative modeling steps need to be completely specified to the agent. One of the strengths of this agent development approach is the agent's ability to apply the logic acquired even in the course of learning the very first example. Thus, steps that are representative of a line of reasoning can be specified and formalized once, and the agent would then be able to propose solutions to similar situations independently. For example, once the agent learned to consider the overall operational force in determining friendly centers of gravity in the assault phase of the Okinawa scenario (Okinawa A.5.0), it could propose the reasoning contained in the analogous circumstances (Okinawa A.9.0, Okinawa G.5.0, and Okinawa G.9.0). Only a minimal amount of new knowledge would need to be specified by the user to introduce new considerations. An example in the current illustration is when an overall force is accepted or rejected as viable for the first time. This automatic learning becomes more efficient with exposure to new scenarios. Most of the modeling for Panama could be automatically inferred by an agent that was first instructed on Okinawa (or vice versa). The learning just illustrated for Okinawa, for example, would directly enable the

generation of the analogous modeling steps for Panama (Panama 5.0 and Panama 9.0). In addition, the consideration of centers of gravity for the enemy perspectives in both scenarios, not illustrated in this thesis for the sake of space, could be almost completely inferred by an agent after learning the friendly perspective, as the modeling steps apply in an identical way, but informed by the alternative perspective (i.e., operational ends, ways, beliefs).

When the aforementioned steps are completed for a case study, the agent would be capable of autonomous problem solving. At that point the instructable nature of the agent would become even more helpful. Having been trained based on one example, it could generate a complete analysis of a new scenario that would be accurate to the extent that the analysis of the first scenario exemplified the appropriate analysis for the new one. As demonstrated in chapter 4, the logic for Okinawa translated to the Panama scenario sufficiently that this learning should be effective, requiring only the specification of new lines of reasoning.

Prototype agents such as those suggested here could be used for several purposes. An immediate application would be to revisit the issues discovered through expert evaluation and make revisions needed to improve the credibility of analysis. Expert evaluation could be repeated, but based on results obtained directly from an agent. A variation that would be beneficial and efficient would be to have experts interact directly with agents and critique the agent during mixed-initiative problem-solving. The result would be a collection of agents that reflect the biases of the experts that taught them. Analysis and further development could then proceed based on the rigorous comparison

of the resulting agents' acquired learning and independent evaluation of the results obtained by them.

After improving the reliability of prototypes in research and development, a further use for developmental agents is to introduce them for use in low risk applications. Education is a particularly promising avenue because the classroom environment can be controlled as necessary to observe the agent's performance and user interaction with it. The classroom is also more tolerant of developmental technology because there is much to gain and little to lose in its use. In educational applications, a center-of-gravity agent could provide the intelligence behind intelligent tutoring systems designed to teach center-of-gravity determination. Previously learned, mature examples could form the basis for lessons and users could be guided by the agent in analyzing them. Students could also introduce new scenarios to the agents for mixed-initiative analysis. The agent's ability to apply and explain the reasoning provided by the experts that taught it would enable it to make available the best available instruction in a one-on-one manner, with practically no limitations on number of students or time spent on instruction. The interface for such intelligent tutoring systems could be Web-enabled or distributed in courseware to make the instruction available to distance learning students as well.

In addition to intelligent tutoring systems, educational application of the proposed agent could also include decision support to classroom planning exercises and operational analysis of historical case studies. This provides the opportunity to experiment with intelligent decision support in a low-risk environment, helping to inform the design of actual systems. This application also generates feedback from the community of experts and students at staff and senior service colleges for the refinement of production agents.

Agent assistance to instruction, both in tutoring systems and in exercise decision support, benefits agent development by providing even more exposure to examples and refinement. Such prototype applications could inform the continued development of the technology for operational decision support in practice. This effort could then transition to the programs that develop emerging decision support systems.

This work also relates to a broader body of related research. As described in chapter 1, efforts are under way between the USAWC and GMU to model the determination of strategic centers of gravity. Therefore an avenue for further research is the integration of results obtained at the strategic and operational levels into combined modeling and agent development. This integration would leverage the progress already made in agent development between GMU and USAWC, reusing parts of the agent's knowledge base and inputs for selected scenarios. In addition, this sort of integration enables a more thorough consideration of the relationship between the operational and strategic levels of analysis. This would likely produce more useful results than treating each level separately.

In addition to tying together the strategic and operational levels of analysis, a broader application of this work might lead to the modeling of related concepts in operational art. An agent that is capable of considering centers of gravity already demonstrates the potential to reason about other concepts of the same class, such as decisive points that affect centers of gravity and the objectives that might obtain from them. As an agent gains competence with an increasing scope of operational concepts, more sophisticated decision support would become possible. With enough sophistication,

agents could one day use this sort of knowledge to analyze operational plans, identify novel alternatives, and assist with branch planning.

Summary

As the military increasingly relies upon information technology to plan and conduct operations, intelligent decision support must advance to assist military decision making tasks that are commonly perceived as too difficult to automate. The technique presented here demonstrates the promise of emerging techniques to such complex problems. It allows for computer-based decision support that does not rely on belief in rigid preconceived notions, but instead facilitates the discernment of human-like problem-solving methods through continued exposure to examples. Intelligent systems thus created will not replace human judgment but complement it. Computers can provide a degree of rigor and thoroughness that humans find unnatural and limiting. Agents allow humans to take advantage of that rigor while furnishing the distinctions that are beyond the computer's competence. Because they are instructable and can engage in mixed-initiative problem solving, intelligent agents are intentionally designed to benefit in this way from the wisdom of human experience. The prospect for human-computer collaboration in military decision making promises more timely and thorough analysis in future operational planning.

APPENDIX A

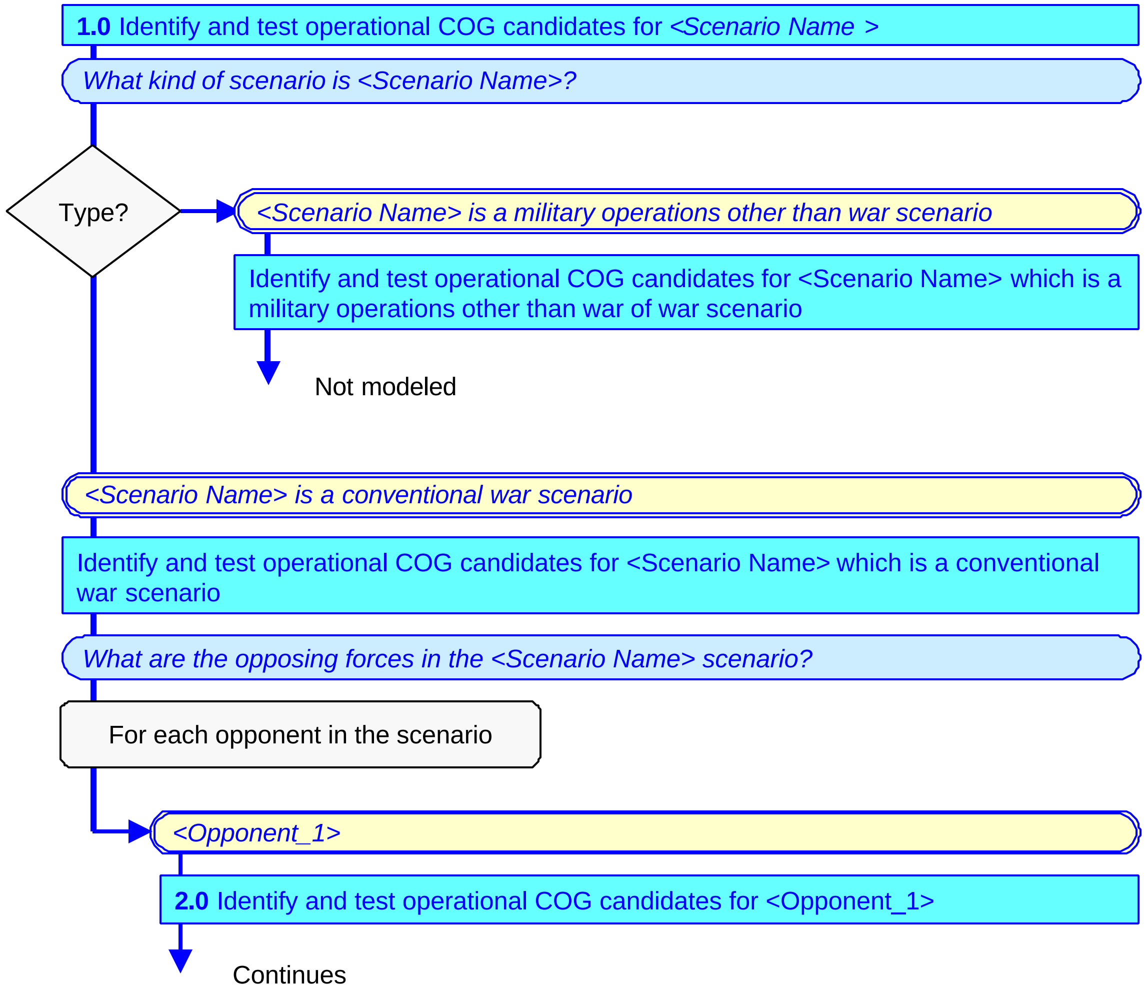
GENERAL MODEL

This appendix contains the general task reduction model for determining operational centers of gravity as described in chapter 4. The modeling procedure is explained in chapter 3.

The following <u>modeling conventions</u> are used in the modeling: Arrows indicate the flow of task decomposition and the logic of the models is generally read along these lines. Tasks are identified in single-bordered boxes (turquoise in color). Questions are depicted in single-bordered rounded boxes (pale blue), and answers are depicted in double-bordered rounded boxes (pale yellow). In addition, questions and answers are distinguished by italicized text. Each task decomposition step includes a beginning task, a question and answer, and a result. The result is either a new task to be decomposed or a solution, depicted as a double-bordered box (green). Additional <u>flow control</u> is shown in gray. Diamonds represent conditionals and rounded rectangles represent processes to be repeated for multiple responses. <u>Parameters</u> designate scenario-specific information as follows. Expressions in angle brackets are simple parameters that can be replaced with scenario-specific text. Terms in square brackets designate optional expressions. Terms in braces indicate a choice to be made among alternatives, which are separated by commas.

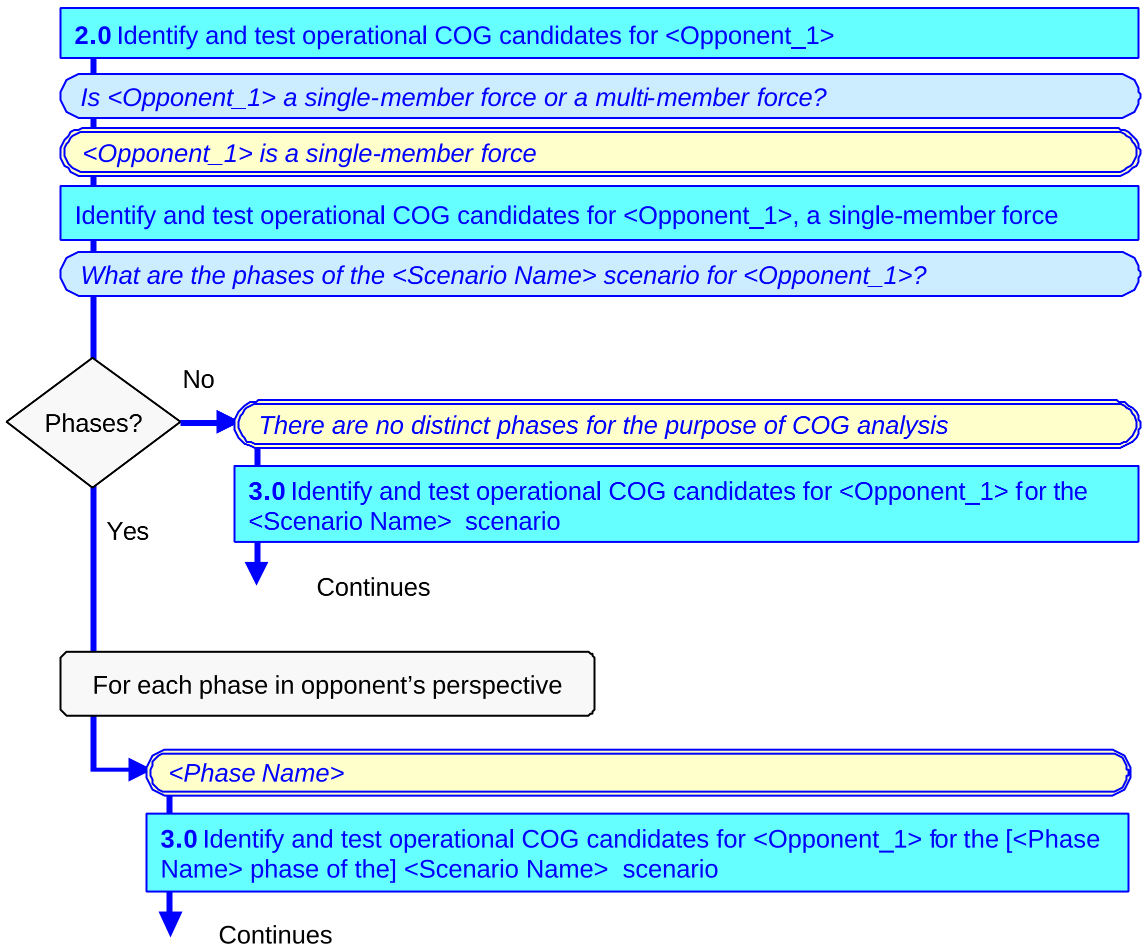
Major modeling steps are indexed with a numbering system for readability. Where modeling continues to another page, the continuation can be found by referencing the index number of the current task and finding that modeling step.

1.0 Determine scenario type and opposing forces



Note: Terms in angle brackets such as *<Scenario Name>*
are placeholders for scenario-specific information

2.0 Conduct COG analysis from opponent perspective



Note: Terms in square brackets such as *[<Phase Name> phase of the]* are optional and included only where appropriate

3.0 Determine friendly and enemy COGs

3.0 Identify and test operational COG candidates for <Opponent_1> for the [<Phase Name> phase of the] <Scenario Name> scenario

What are the operational aims of <Opponent_1> in the <Phase Name> phase?

For each aim (preferably a single aim)

<Operational Aim>

Identify and test operational COG candidates for <Opponent_1> relative to the operational aim <Operational Aim> for the [<Phase Name> phase of the] <Scenario Name> scenario

What operational actions by <Opponent_1> are required to accomplish the aim <Operational Aim>?

For each task (preferably a single task)

<Operational Task>

4.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the sources of strength that enable <Opponent_1> to <Operational Task> to <Operational Aim> for the [<Phase Name> phase of the] <Scenario Name> scenario

Continues

8.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the sources of strength that <Opponent_1> could defeat in order to <Operational Task> to <Operational Aim> for the [<Phase Name> phase of the] <Scenario Name> scenario

Continues

4.0 Friendly COG analysis

4.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the sources of strength that enable <Opponent_1> to <Operational Task> to <Operational Aim> [for the <Phase Name> phase of the] <Scenario Name> scenario

What are the sources of strength that provide ***<****Opponent_1> the capability to <Operational Task> to <Operational Aim>?*

I consider forces that provide the physical strength to conduct the operation

5.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the forces that provide <Opponent_1> the physical strength to <Operational Task> to <Operational Aim> [for the <Phase Name> phase]

Continues

I consider other capabilities that provide the physical strength to conduct the operation

6.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the operational capabilities that provide <Opponent_1> the physical strength to <Operational Task> to <Operational Aim> [for the <Phase Name> phase]

Continues

I consider sources of strength that provide the freedom of action to conduct the operation

7.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the other sources of strength that provide <Opponent_1> the freedom of action to <Operational Task> to <Operational Aim> [for the <Phase Name> phase]

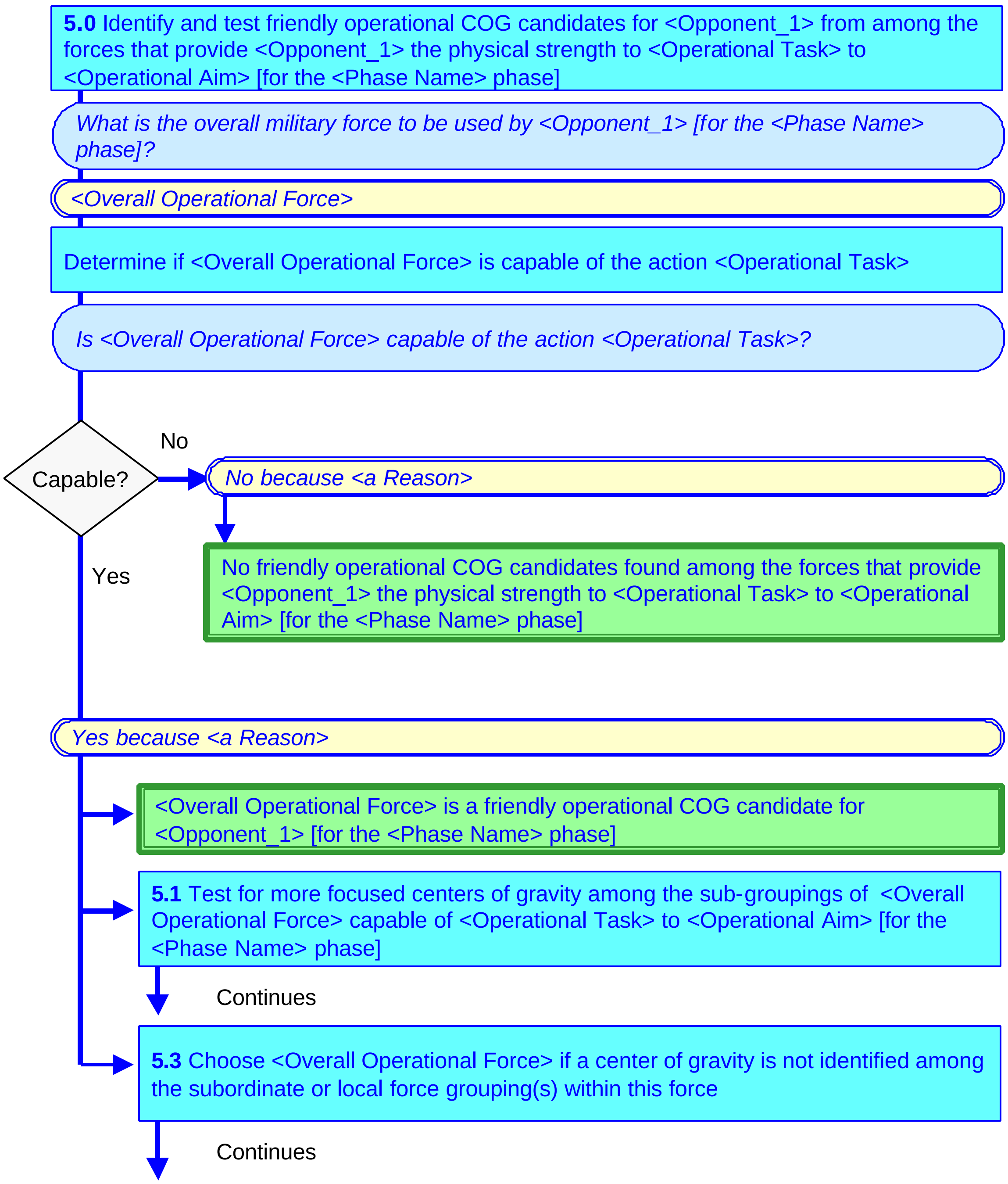
Continues

I consider sources of strength that provide the will to fight to conduct the operation

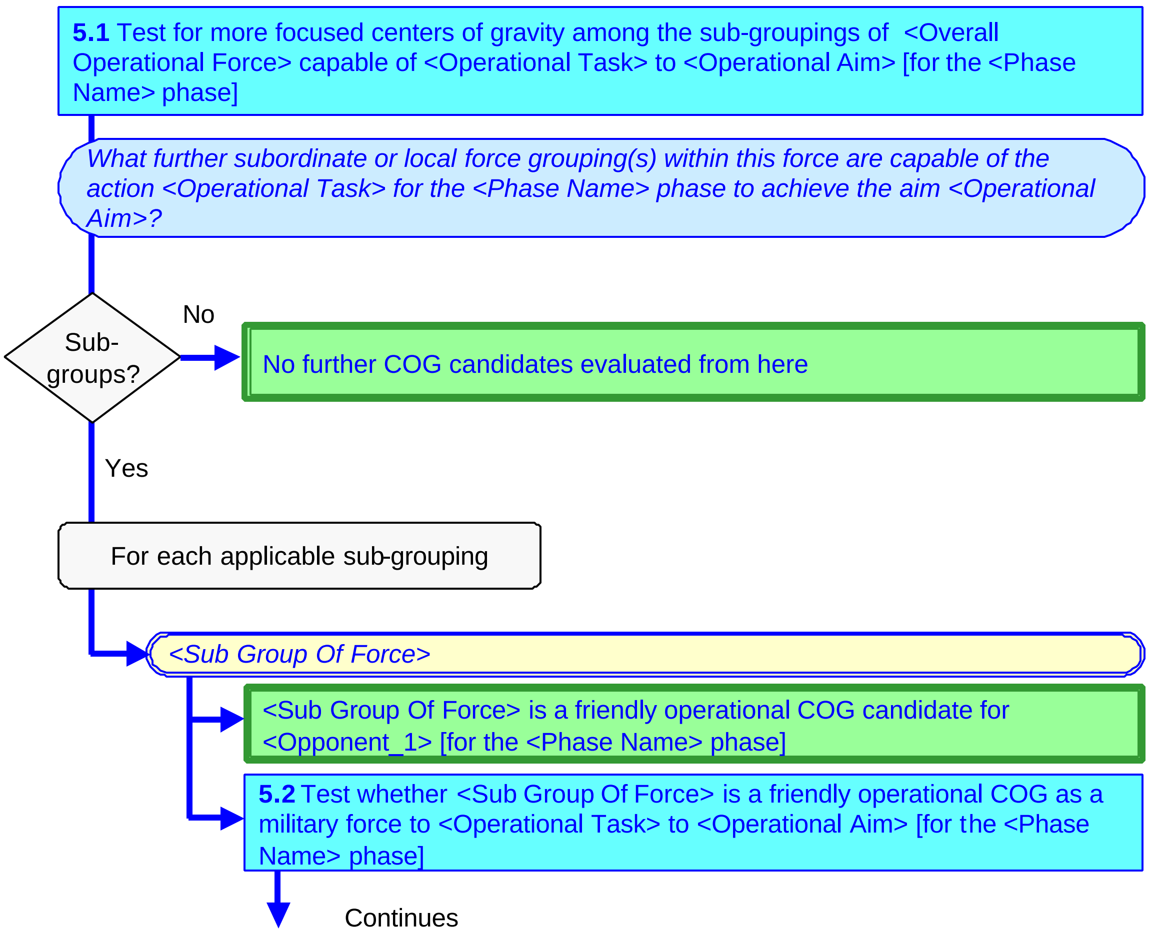
7.0 Identify and test friendly operational COG candidates for <Opponent_1> from among the other sources of strength that provide <Opponent_1> the will to fight to <Operational Task> to <Operational Aim> [for the <Phase Name> phase]

Continues

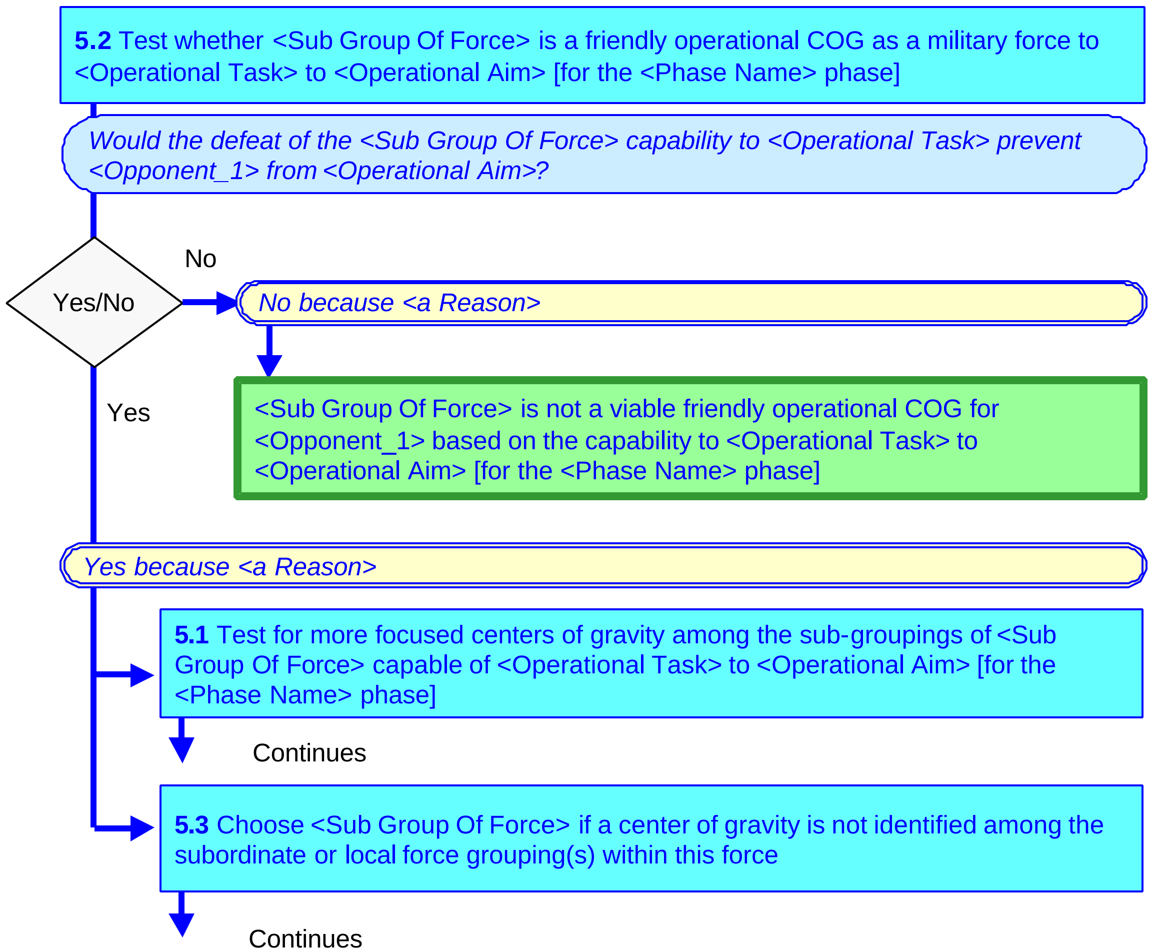
5.0 Friendly forces



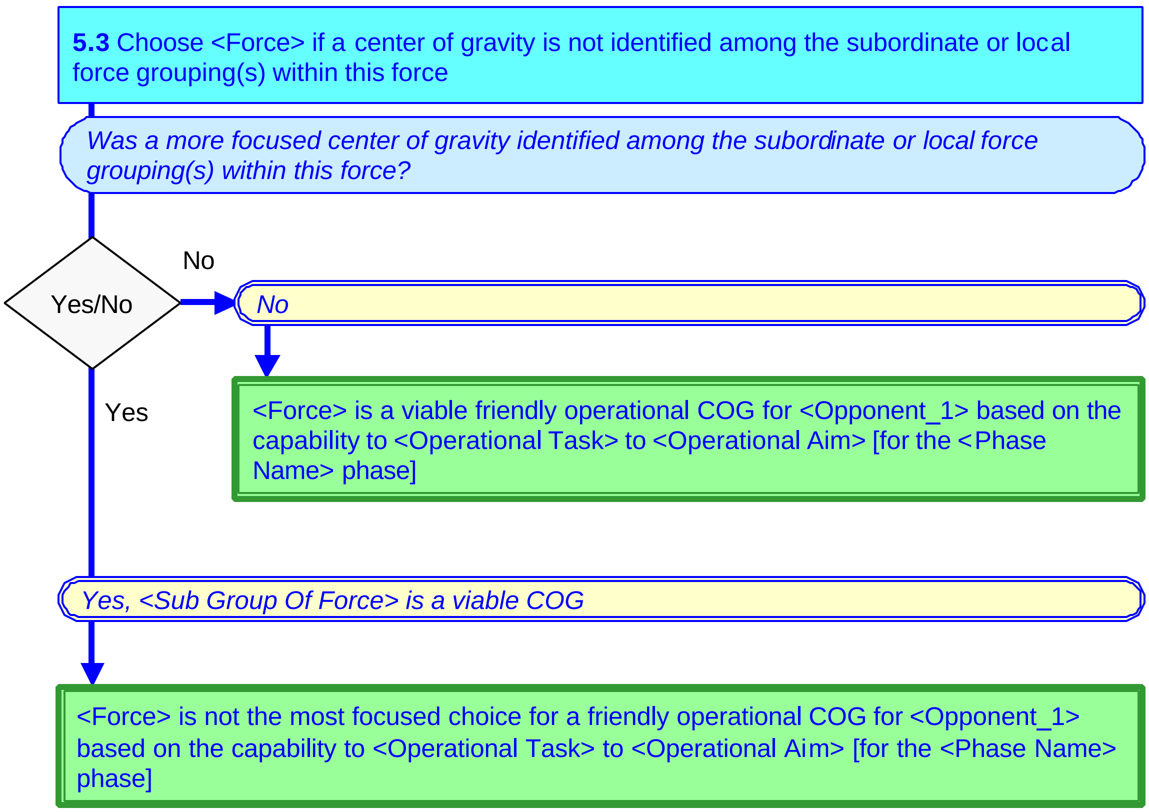
5.1 Friendly forces



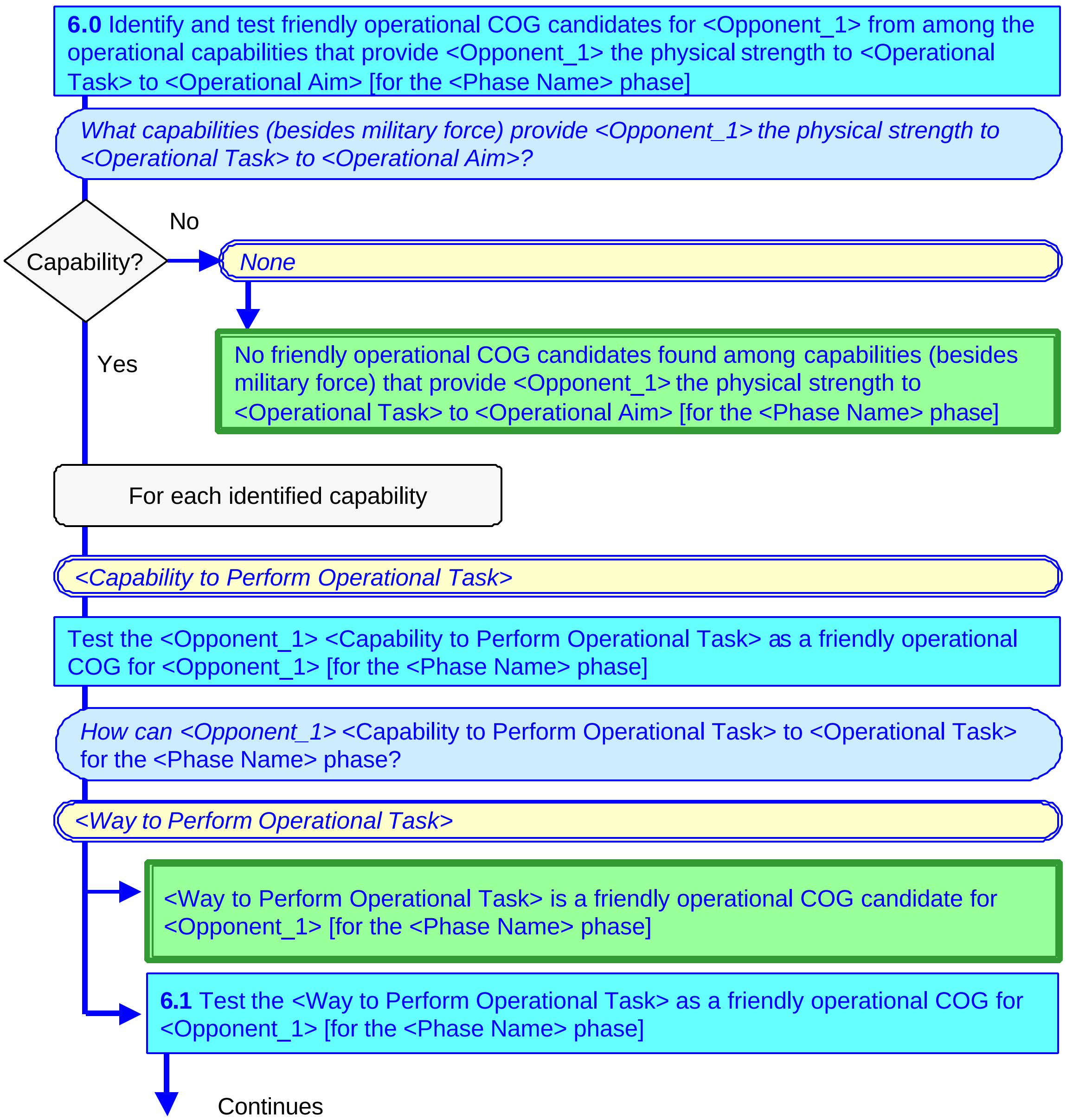
5.2 Friendly forces



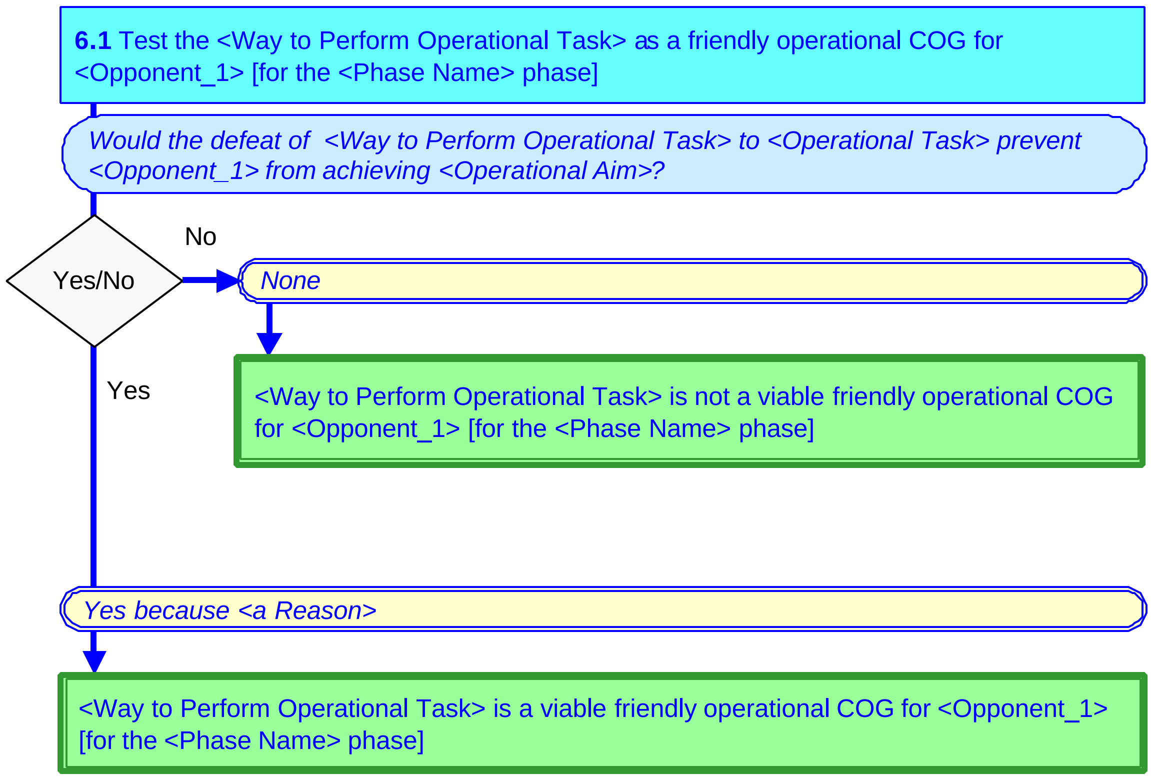
5.3 Friendly forces



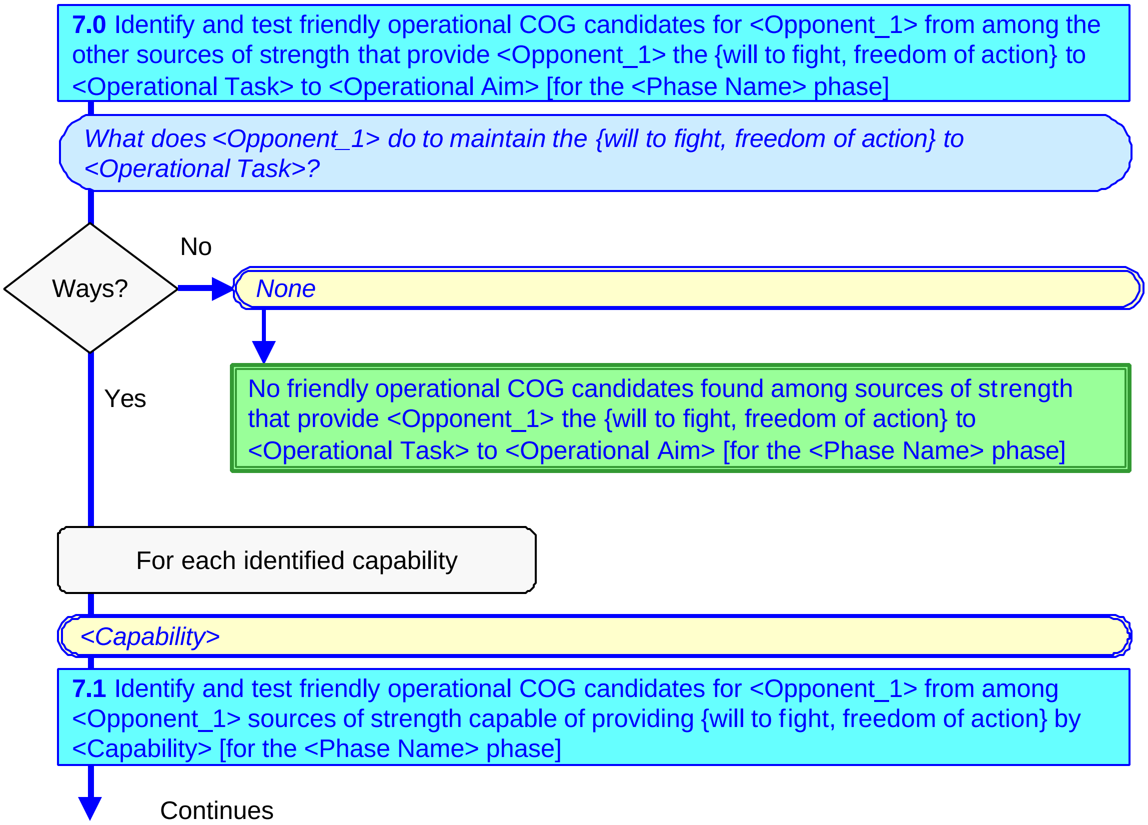
6.0 Friendly capabilities



6.1 Friendly capabilities

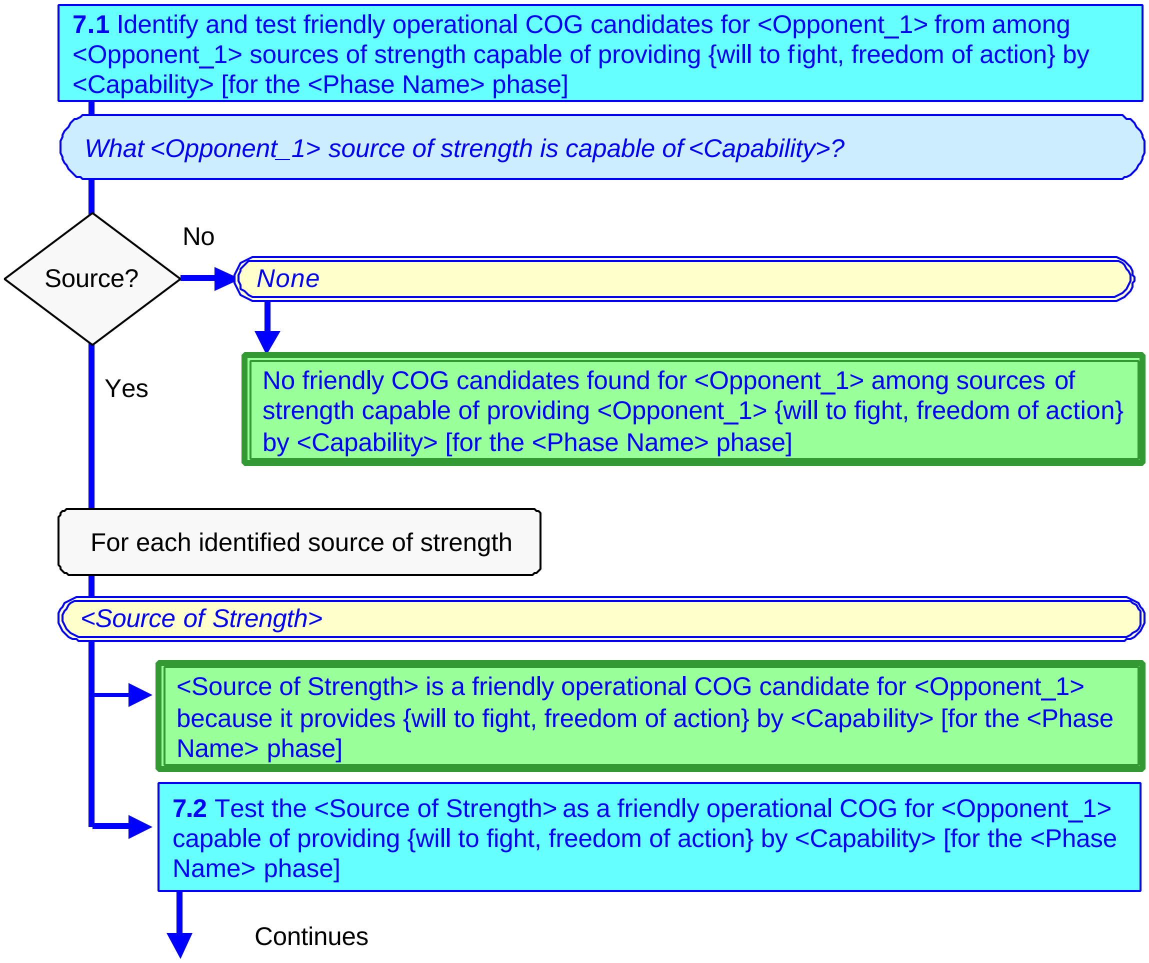


7.0 Friendly will to fight and freedom of action

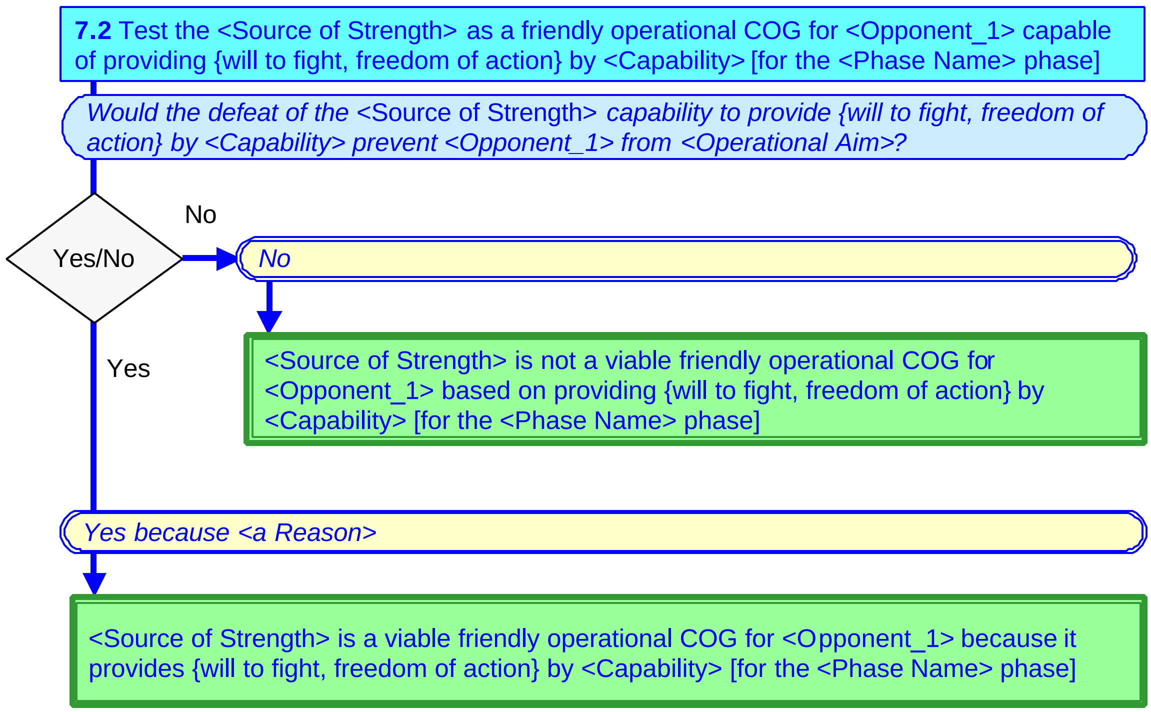


Note: Terms in braces such as *{will to fight, freedom of action}* indicate a choice to be made among alternatives, and that choice should be consistent in each instance

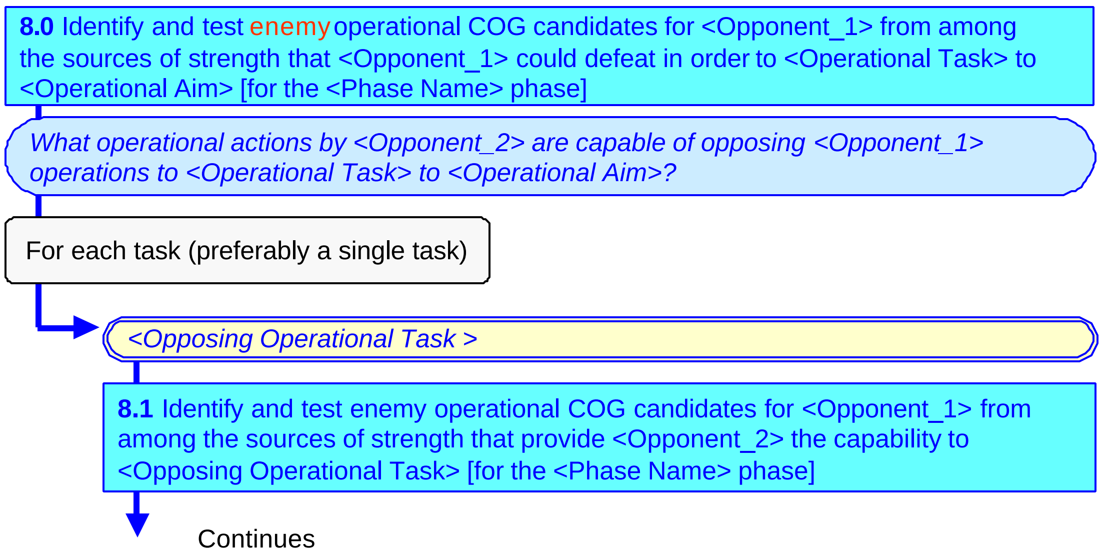
7.1 Friendly will to fight and freedom of action



7.2 Friendly will to fight and freedom of action



8.0 Enemy COG analysis



8.1 Enemy COG analysis

8.1 Identify and test enemy operational COG candidates for <Opponent_1> from among the sources of strength that provide <Opponent_2> the capability to <Opposing Operational Task> [for the <Phase Name> phase]

What are the sources of strength that <Opponent_2> possesses to <Opposing Operational Task>?

I consider forces that provide the physical strength to oppose the operation

9.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the forces that provide <Opponent_2> the physical strength to <Opposing Operational Task> [for the <Phase Name> phase]

Continues

I consider other capabilities that provide the physical strength to oppose the operation

10.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the operational capabilities that provide <Opponent_2> the physical strength to <Opposing Operational Task> [for the <Phase Name> phase]

Continues

I consider sources of strength that provide the freedom of action to oppose the operation

11.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the other sources of strength that provide <Opponent_2> the freedom of action to <Opposing Operational Task> [for the <Phase Name> phase]

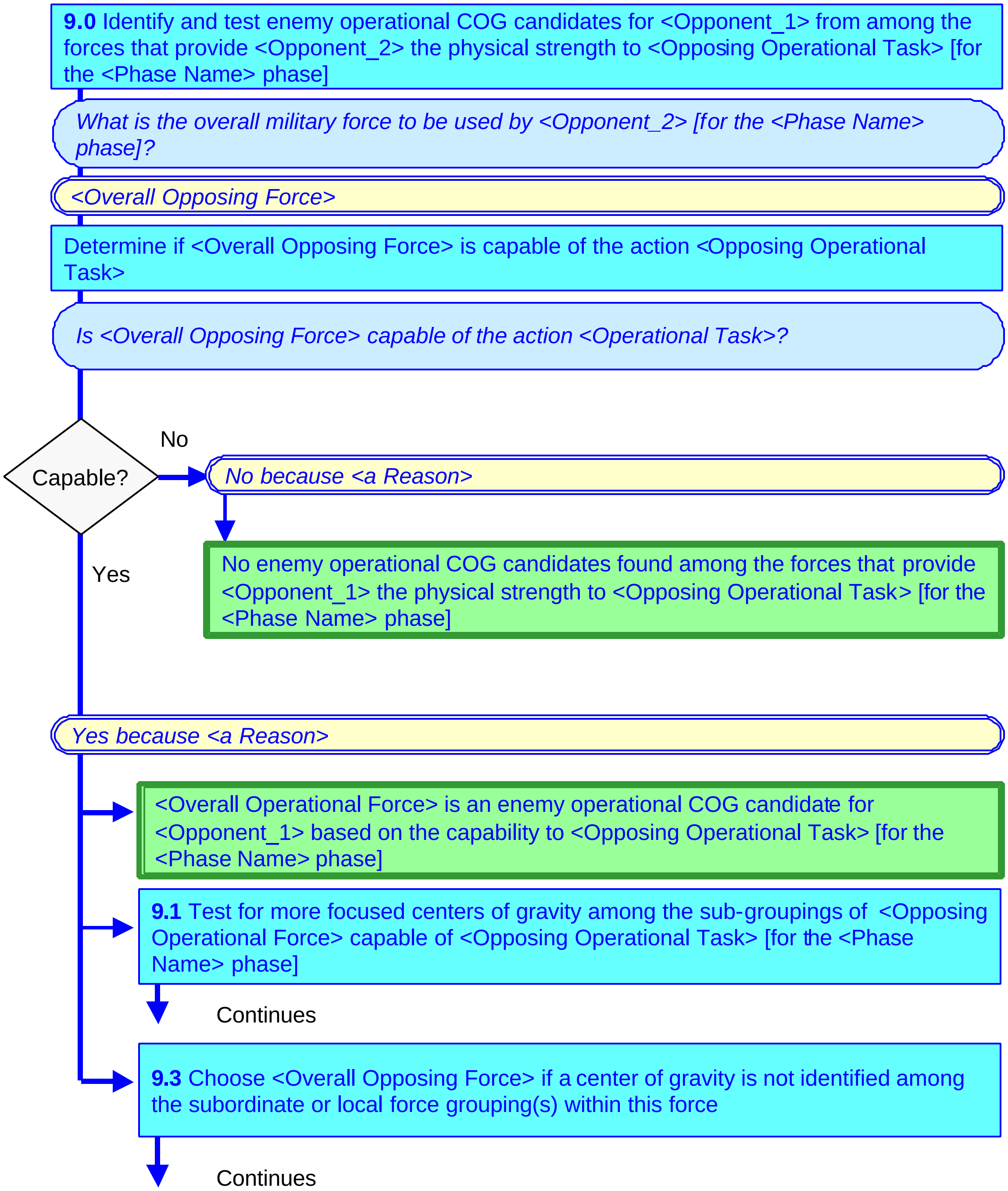
Continues

I consider sources of strength that provide the will to fight to oppose the operation

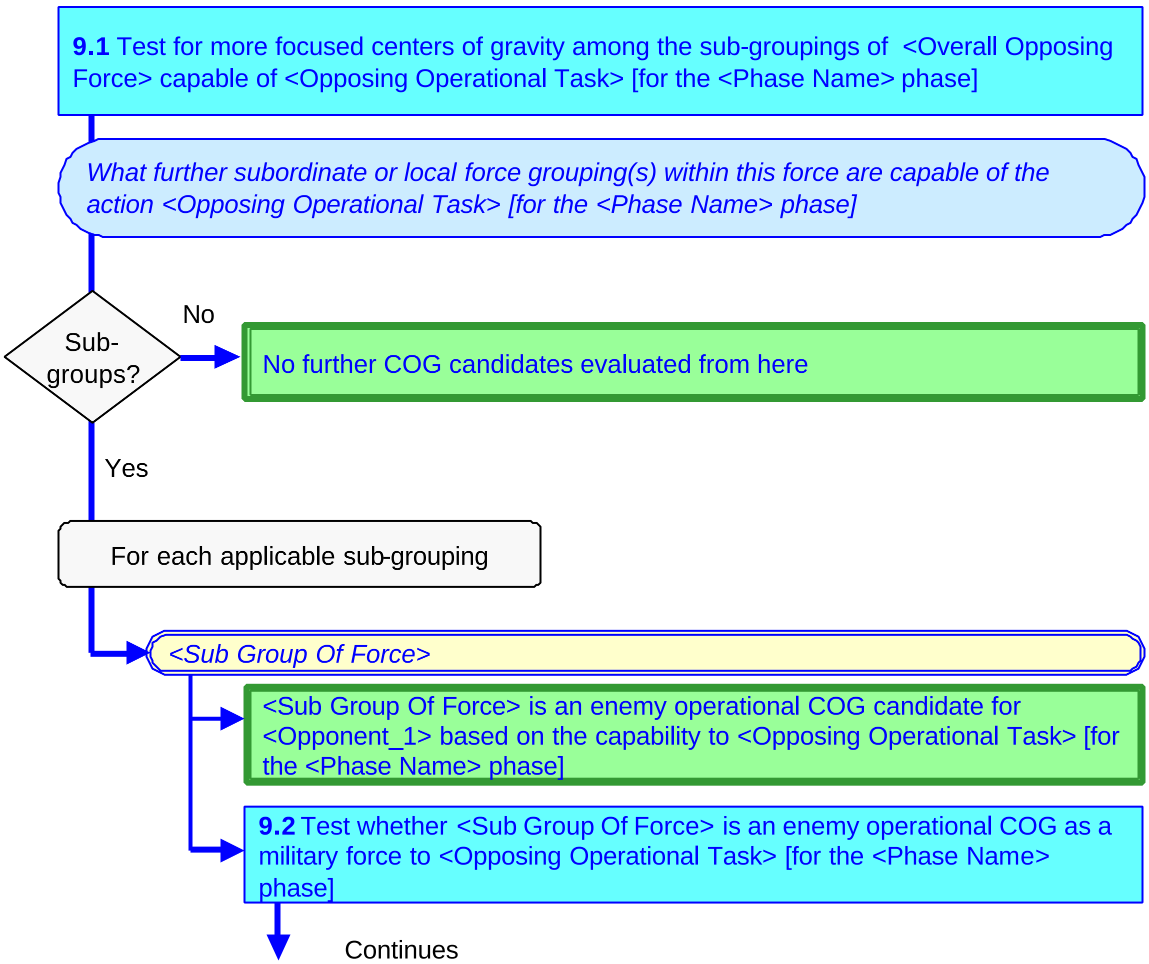
11.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the other sources of strength that provide <Opponent_2> the will to fight to <Opposing Operational Task> [for the <Phase Name> phase]

Continues

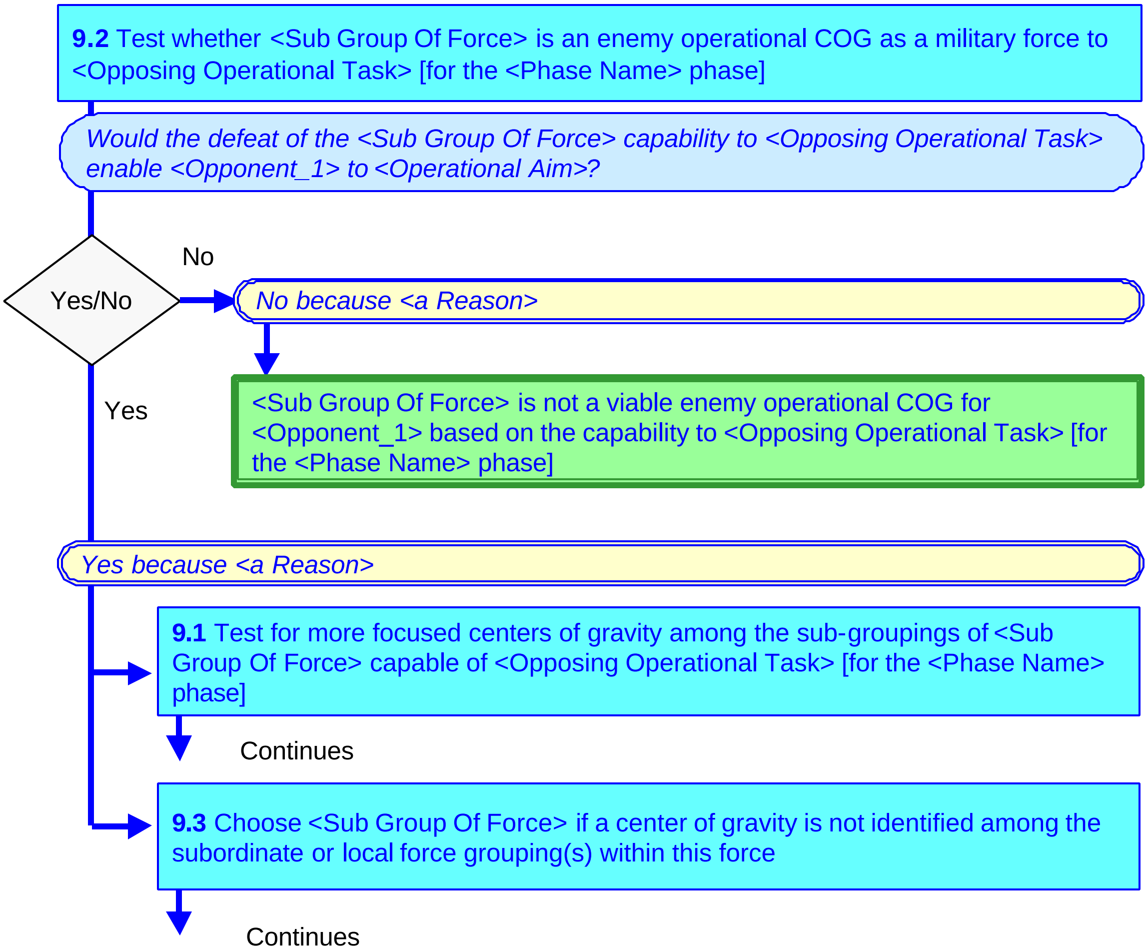
9.0 Enemy forces



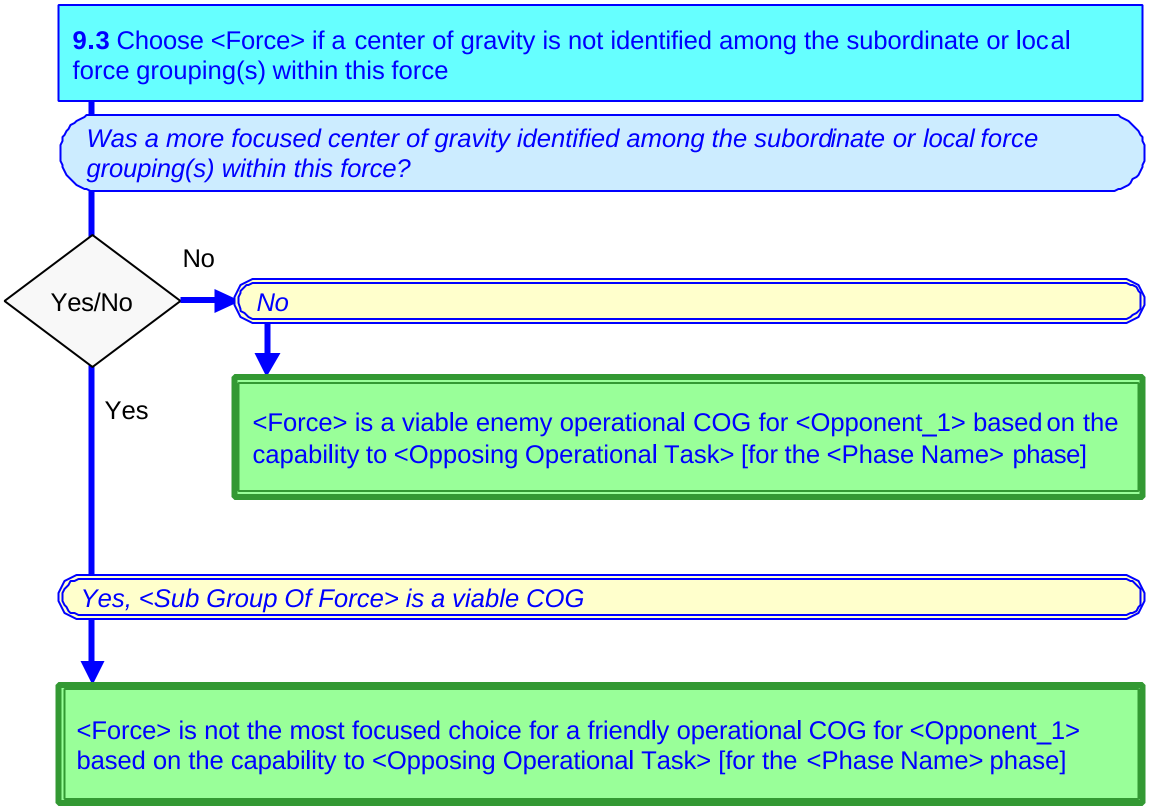
9.1 Enemy forces



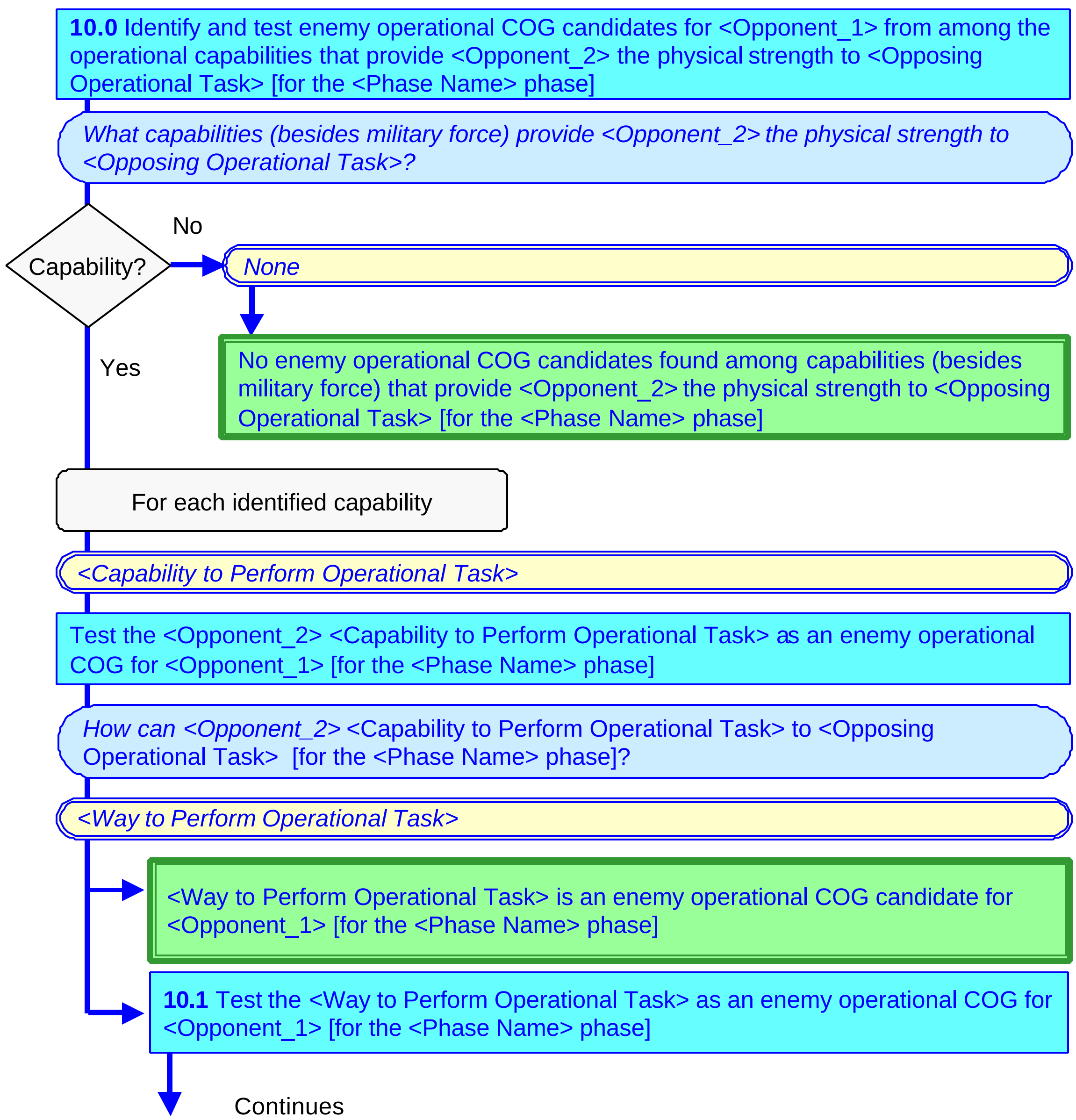
9.2 Enemy forces



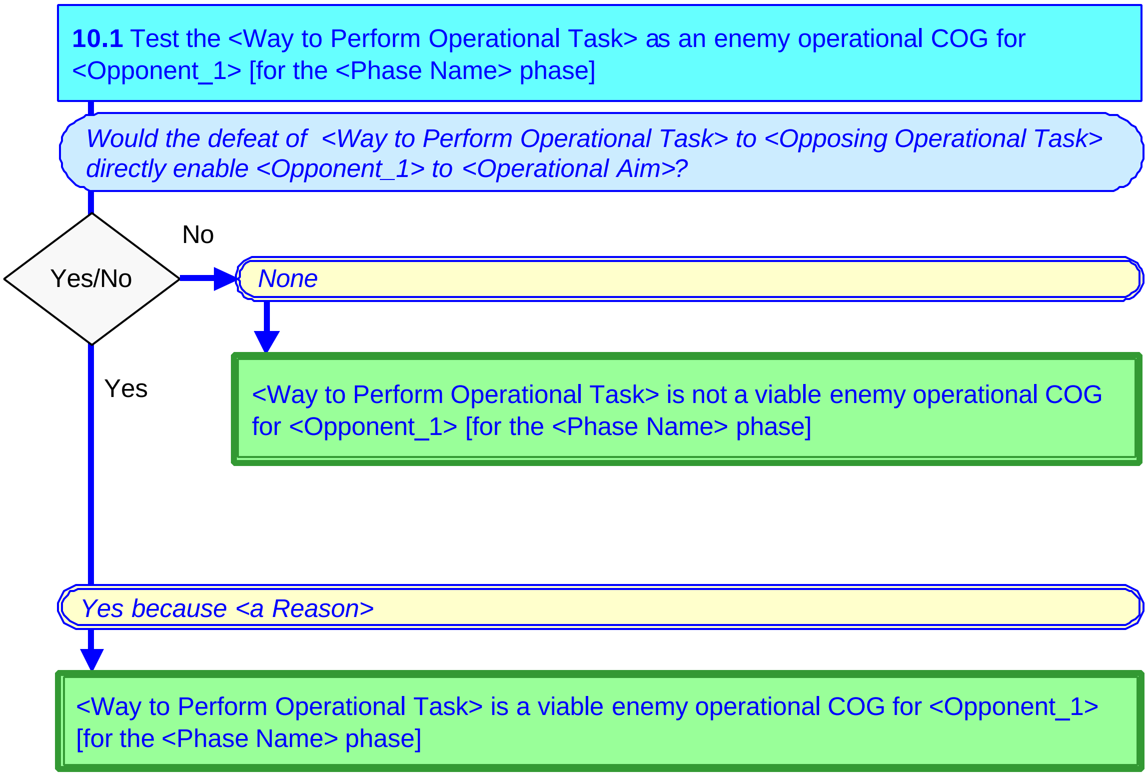
9.3 Enemy forces



10.0 Enemy capabilities



10.1 Enemy capabilities



11.0 Enemy will to fight and freedom of action

11.0 Identify and test enemy operational COG candidates for <Opponent_1> from among the other sources of strength that provide <Opponent_2> the {will to fight, freedom of action} to <Opposing Operational Task> [for the <Phase Name> phase]

What does <Opponent_2> do to maintain the {will to fight, freedom of action} to <Opposing Operational Task>?

Ways?

No

None

No enemy operational COG candidates found among sources of strength that provide <Opponent_2> the {will to fight, freedom of action} to <Opposing Operational Task> [for the <Phase Name> phase]

Yes

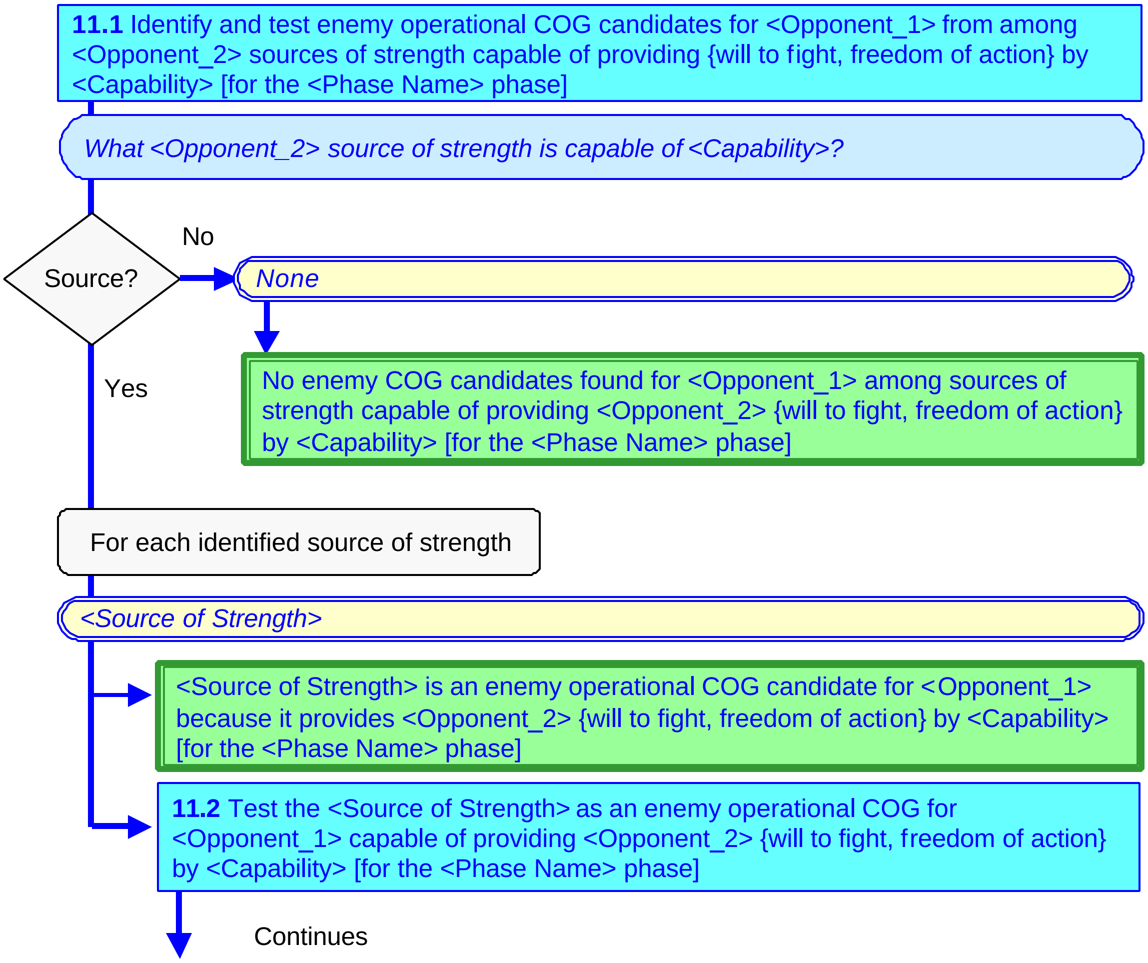
For each identified capability

<Capability>

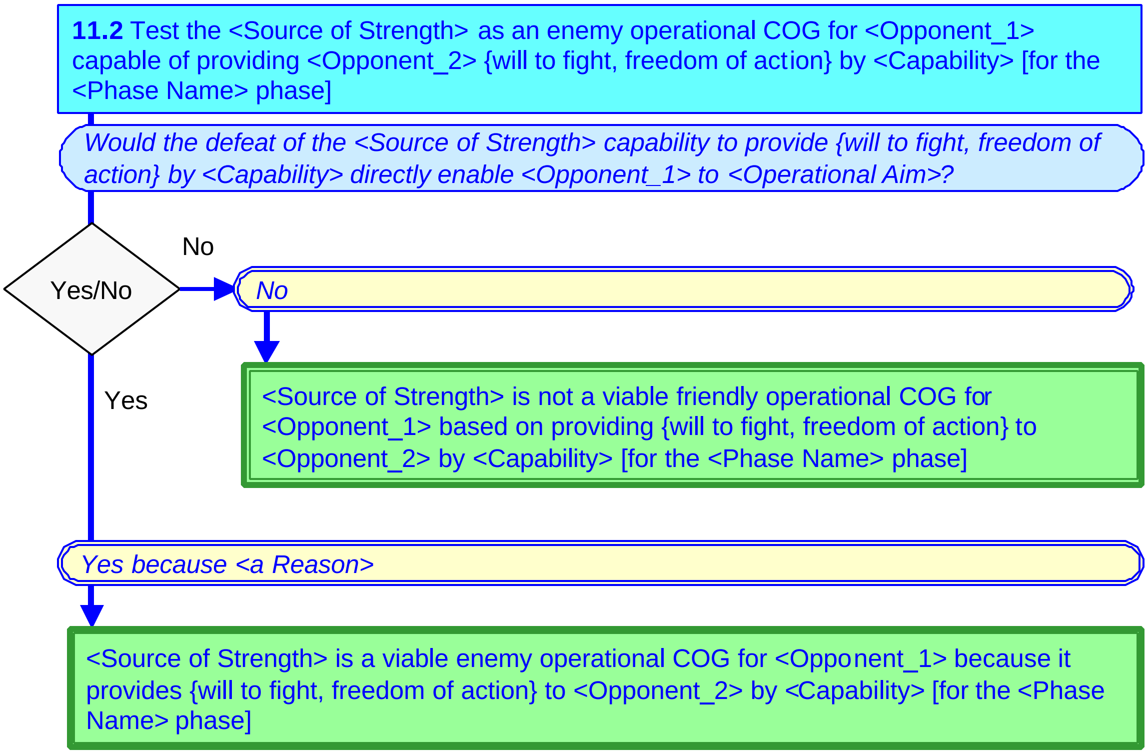
11.1 Identify and test enemy operational COG candidates for <Opponent_1> from among <Opponent_2> sources of strength capable of providing {will to fight, freedom of action} by <Capability> [for the <Phase Name> phase]

Continues

11.1 Enemy will to fight and freedom of action



11.2 Enemy will to fight and freedom of action



APPENDIX B

MODELING FOR OKINAWA CASE STUDY

This appendix contains the task reduction modeling done for the Okinawa scenario. This modeling is explained in detail in chapter 4. The modeling conventions are those explained in chapter 3 and shown in appendix A. Modeling steps have been indexed to correspond to those in the general model for the readability of the model and for ease of comparison between models. Where modeling branches by phase, model numbers are prefixed accordingly (i.e., "A" for the assault phase and "G" for the ground phase). Where modeling continues to another page, the continuation can be found by referencing the index number of the current task and finding that modeling step.

Okinawa 1.0

1.0 Identify and test operational COG candidates for Okinawa_1945

What kind of scenario is Okinawa_1945?

Okinawa_1945 is a conventional war scenario

Identify and test operational COG candidates for Okinawa_1945 which is a major theater of war scenario

What are the opposing forces in the Okinawa_1945 scenario?

US_1945

2.0 Identify and test operational COG candidates for US_1945

Continues

Japan_1945

Identify and test operational COG candidates for Japan_1945

Not modeled

Okinawa 2.0

2.0 Identify and test operational COG candidates for US_1945

Is US_1945 a single-member force or a multi-member force?

US_1945 is a single-member force

Identify and test operational COG candidates for US_1945, a single-member force

What are the phases of the Okinawa_1945 scenario for US_1945?

- *Assault on Okinawa*

  A.3.0 Identify and test operational COG candidates for US_1945 for the assault on Okinawa phase of the Okinawa_1945 scenario

  Continues

- *Ground campaign on Okinawa*

  G.3.0 Identify and test operational COG candidates for US_1945 for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

  Continues

Okinawa A.3.0

A.3.0 Identify and test operational COG candidates for US_1945 for the assault on Okinawa phase of the Okinawa_1945 scenario

What are the operational aims of US_1945 in the assault on Okinawa phase?

Establish a foothold on Okinawa

Identify and test operational COG candidates for US_1945 relative to the operational aim establish a foothold on Okinawa for the assault on Okinawa phase of the Okinawa_1945 scenario

What operational actions by US_1945 are required to accomplish the aim establish a foothold on Okinawa?

Conduct amphibious forcible entry

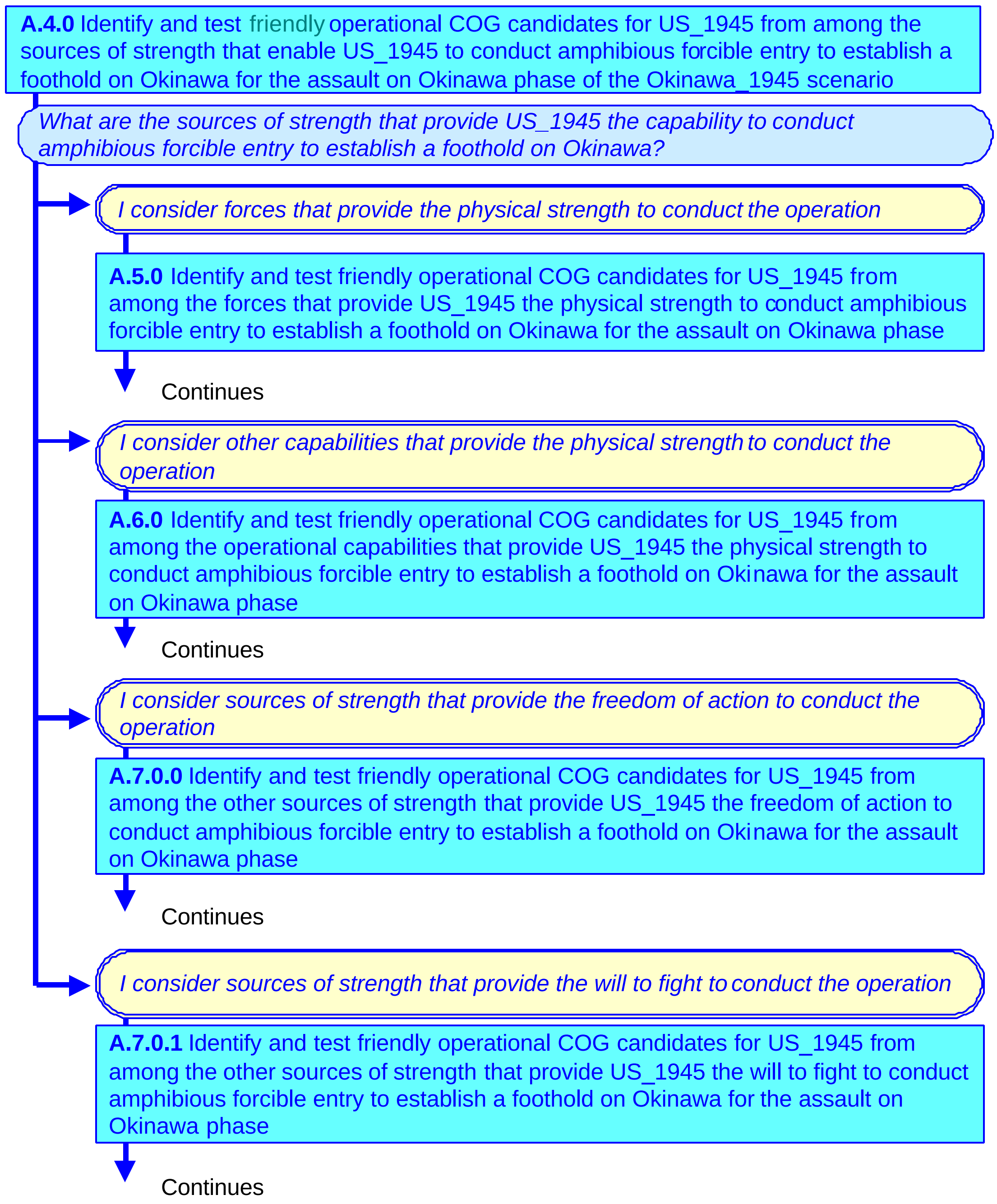
A.4.0 Identify and test friendly operational COG candidates for US_1945 from among the sources of strength that enable US_1945 to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase of the Okinawa_1945 scenario

Continues

A.8.0 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that US_1945 could defeat in order to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase of the Okinawa_1945 scenario

Continues

Okinawa A.4.0



A.4.0 Identify and test friendly operational COG candidates for US_1945 from among the sources of strength that enable US_1945 to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase of the Okinawa_1945 scenario
What are the sources of strength that provide US_1945 the capability to conduct amphibious forcible entry to establish a foothold on Okinawa?
I consider forces that provide the physical strength to conduct the operation
A.5.0 Identify and test friendly operational COG candidates for US_1945 from among the forces that provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase
Continues
I consider other capabilities that provide the physical strength to conduct the operation
A.6.0 Identify and test friendly operational COG candidates for US_1945 from among the operational capabilities that provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase
Continues
I consider sources of strength that provide the freedom of action to conduct the operation
A.7.0.0 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the freedom of action to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase
Continues
I consider sources of strength that provide the will to fight to conduct the operation
A.7.0.1 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the will to fight to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase
Continues

Okinawa A.5.0

A.5.0 Identify and test friendly operational COG candidates for US_1945 from among the forces that provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What is the overall military force to be used by US_1945 for the assault on Okinawa phase?

TF51_Joint_Expeditionary_Force

Determine if TF51_Joint_Expeditionary_Force is capable of the action conduct amphibious forcible entry

Is TF51_Joint_Expeditionary_Force capable of the action conduct amphibious forcible entry?

Yes because it is organized with ground and amphibious support forces

TF51_Joint_Expeditionary_Force is a friendly operational COG candidate for US_1945 for the assault on Okinawa phase

A.5.1.0 Test for more focused centers of gravity among the sub-groupings of TF51_Joint_Expeditionary_Force capable of conducting amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Continues

A.5.3.0 Choose TF51_Joint_Expeditionary_Force if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

Yes, Main_Landing_Forces is a viable COG

TF51_Joint_Expeditionary_Force is not the most focused choice for a friendly operational COG for US_1945 based on the capability to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.5.1.0

A.5.1.0 Test for more focused centers of gravity among the sub-groupings of TF51_Joint_Expeditionary_Force capable of conducting amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What further subordinate or local force grouping(s) within this force are capable of the action conduct amphibious forcible entry for the assault on Okin awa phase to achieve the aim establish a foothold on Okinawa?

Main_Landing_Forces

Main_Landing_Forces is a friendly operational COG candidate for US_1945 for the assault on Okinawa phase

A.5.2.0 Test whether Main_Landing_Forces is a friendly operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Continues

Okinawa A.5.2.0

A.5.2.0 Test whether Main_Landing_Forces is a friendly operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Would the defeat of the Main_Landing_Forces capability to conduct amphibious forcible entry prevent US_1945 from establishing a foothold on Okinawa?

Yes because there are not enough remaining forces with this capability

A.5.1.1 Test for more focused centers of gravity among the sub-groupings of Main_Landing_Forces capable of conducting amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Continues

A.5.3.1 Choose Main_Landing_Forces if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

Main_Landing_Forces is a viable friendly operational COG for US_1945 based on the capability to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.5.1.1

A.5.1.1 Test for more focused centers of gravity among the sub-groupings of Main_Landing_Forces capable of conducting amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What further subordinate or local force grouping(s) within this force are capable of the action conduct amphibious forcible entry for the assault on Okinawa phase to achieve the aim establish a foothold on Okinawa?

- *TF53_Northern_Attack_Force*
  - TF53_Northern_Attack_Force is a friendly operational COG candidate for US_1945 for the assault on Okinawa phase
  - **A.5.2.1** Test whether TF53_Northern_Attack_Force is a friendly operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

    Continues
- *TF55_Southern_Attack_Force*
  - TF55_Southern_Attack_Force is a friendly operational COG candidate for US_1945 for the assault on Okinawa phase
  - **A.5.2.2** Test whether TF55_Southern_Attack_Force is a friendly operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

    Continues

Okinawa A.5.2.1

A.5.2.1 Test whether TF53_Northern_Attack_Force is a friendly operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Would the defeat of the TF53_Northern_Attack_Force capability to conduct amphibious forcible entry prevent US_1945 from establishing a foothold on Okinawa?

No because TF55_Southern_Attack_Force also has this capability

TF53_Northern_Attack_Force is not a viable friendly operational COG for US_1945 based on the capability to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.5.2.2

A.5.2.2 Test whether TF55_Southern_Attack_Force is an operational COG as a military force to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Would the defeat of the TF55_Southern_Attack_Force capability to conduct amphibious forcible entry prevent US_1945 from establishing a foothold on Okinawa?

No because TF53_Northern_Attack_Force also has this capability

TF55_Southern_Attack_Force is not a viable friendly operational COG for US_1945 based on the capability to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.6.0

A.6.0 Identify and test friendly operational COG candidates for US_1945 from among the operational capabilities that provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What capabilities (besides military force) provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa?

None

No friendly operational COG candidates found among capabilities (besides military force) that provide US_1945 the physical strength to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.7.0.0

A.7.0.0 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the freedom of action to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What sources of strength provide US_1945 the freedom of action to conduct amphibious forcible entry to establish a foothold on Okinawa?

None

No friendly operational COG candidates found among sources of strength that provide US_1945 the freedom of action to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.7.0.1

A.7.0.1 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the will to fight to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

What sources of strength provide US_1945 the will to fight to conduct amphibious forcible entry to establish a foothold on Okinawa?

None

No friendly operational COG candidates found among sources of strength that provide US_1945 the will to fight to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase

Okinawa A.8.0

A.8.0 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that US_1945 could defeat in order to conduct amphibious forcible entry to establish a foothold on Okinawa for the assault on Okinawa phase of the Okinawa_1945 scenario

What operational actions by Japan_1945 are capable of opposing US_1945 operations to conduct amphibious forcible entry to establish a foothold on Okinawa?

Interdict operational forces/targets (US_1945 landing forces)

A.8.1.0 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to interdict US_1945 landing forces for the assault on Okinawa phase

Continues

Control operationally significant land area (landing beaches)

A.8.1.1 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to control landing beaches for the assault on Okinawa phase

Continues

Okinawa A.8.1.0

A.8.1.0 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to interdict US_1945 landing forces for the assault on Okinawa phase

What are the sources of strength that Japan_1945 possesses to interdict US_1945 landing forces?

I consider forces that provide the physical strength to oppose the operation

A.9.0 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to interdict US_1945 landing forces for the assault on Okinawa phase

Continues

I consider other capabilities that provide the physical strength to oppose the operation

A.10.0.0 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to interdict US_1945 landing forces for the assault on Okinawa phase

Continues

I consider sources of strength that provide the freedom of action to oppose the operation

A.11.0.0.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to interdict US_1945 landing forces for the assault on Okinawa phase

Continues

I consider sources of strength that provide the will to fight to oppose the operation

A.11.0.1.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the will to fight to interdict US_1945 landing forces for the assault on Okinawa phase

Continues

Okinawa A.9.0

A.9.0 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to interdict US_1945 landing forces for the assault on Okinawa phase

What is the overall military force to be used by Japan_1945 for the assault on Okinawa phase that is capable of the action interdict US_1945 landing forces?

Japanese_Forces_Okinawa

Determine if Japanese_Forces_Okinawa are capable of the action interdict US_1945 landing forces

Is Japanese_Forces_Okinawa capable of the action interdict US_1945 landing forces?

Yes because it includes forces that can perform interdiction of operational targets

Japanese_Forces_Okinawa is an enemy operational COG candidate for US_1945 for the assault on Okinawa phase

A.9.1.0 Test for more focused centers of gravity among the sub-groupings of Japanese_Forces_Okinawa capable of interdicting US_1945 landing forces for the assault on Okinawa phase

Continues

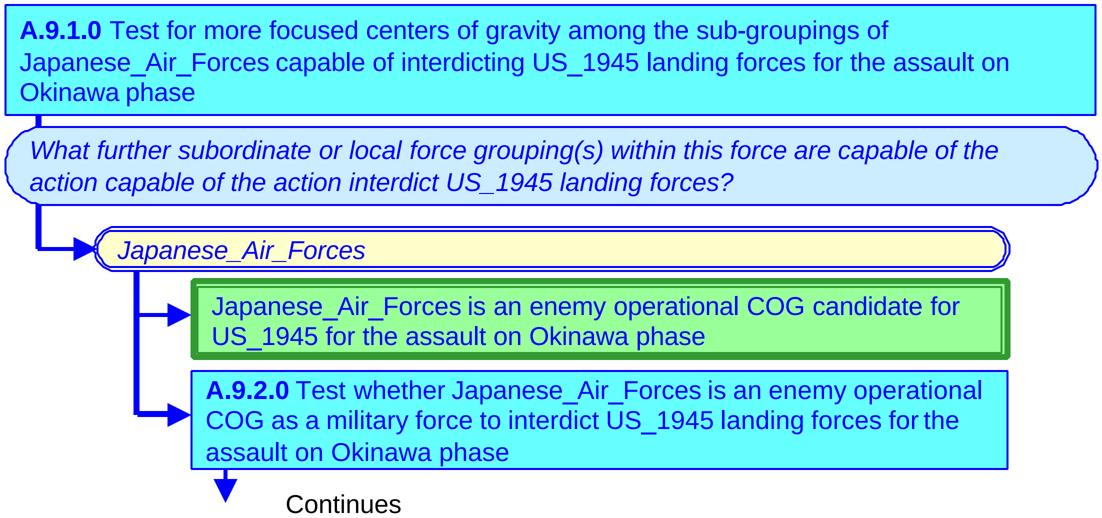
A.9.3.0 Choose Japanese_Forces_Okinawa if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

Yes, Japanese_Air_Forces is a viable COG

Japanese_Forces_Okinawa is not the most focused choice for an enemy operational COG for US_1945 among the forces of Japan_1945 based on the capability to interdict US_1945 landing forces for the assault on Okinawa phase

Okinawa A.9.1.0



Okinawa A.9.2.0

A.9.2.0 Test whether Japanese_Air_Forces is an enemy operational COG as a military force to interdict US_1945 landing forces for the assault on Okinawa phase

Would the defeat of the Japanese_Air_Forces capability to interdict US_1945 landing forces directly enable US_1945 to establish a foothold on Okinawa?

Yes because Japanese aircraft pose the most significant threat to forces on beaches and afloat

A.9.1.1 Test for more focused centers of gravity among the sub-groupings of Japanese_Air_Forces capable of interdicting US_1945 landing forces for the assault on Okinawa phase

Continues

A.9.3.1 Choose Japanese_Air_Forces if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

Japanese_Air_Forces is a viable enemy operational COG for US_1945 based on the capability to interdict US_1945 landing forces for the assault on Okinawa phase

Okinawa A.9.1.1

A.9.1.1 Test for more focused centers of gravity among the sub-groupings of Japanese_Forces_Okinawa capable of interdicting US_1945 landing forces for the assault on Okinawa phase

What further subordinate or local force grouping(s) within this force are capable of the action capable of the action interdict US_1945 landing forces?

None

No further COG candidates evaluated from here

Okinawa A.10.0.0

A.10.0.0 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to interdict US_1945 landing forces for the assault on Okinawa phase

What capabilities (besides military force) provide Japan_1945 the physical strength to interdict US_1945 landing forces?

None

No friendly operational COG candidates found among capabilities (besides military force) that provide Japan_1945 the physical strength to interdict US_1945 landing forces for the assault on Okinawa phase

Okinawa A.11.0.0.0

A.11.0.0.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to interdict US_1945 landing forces for the assault on Okinawa phase

What sources of strength provide Japan_1945 the freedom of action to interdict US_1945 landing forces?

None

No friendly operational COG candidates found among sources of strength that provide Japan_1945 the freedom of action to interdict US_1945 landing forces for the assault on Okinawa phase

Okinawa A.11.0.1.0

A.11.0.1.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the will to fight to interdict US_1945 landing forces for the assault on Okinawa phase

What sources of strength provide Japan_1945 the will to fight to interdict US_1945 landing forces?

None

No friendly operational COG candidates found among sources of strength that provide Japan_1945 the will to fight to interdict US_1945 landing forces for the assault on Okinawa phase

Okinawa A.8.1.1

A.8.1.1 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to control landing beaches for the assault on Okinawa phase

What are the sources of strength that Japan_1945 possesses to control landing beaches?

I consider forces that provide the physical strength to oppose the operation

A.9.0.1 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to control landing beaches for the assault on Okinawa phase

Continues

I consider other capabilities that provide the physical strength to oppose the operation

A.10.0.1 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to control landing beaches for the assault on Okinawa phase

Continues

I consider sources of strength that provide the freedom of action to oppose the operation

A.11.0.0.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to control landing beaches for the assault on Okinawa phase

Continues

I consider sources of strength that provide the will to fight to oppose the operation

A.11.0.1.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the will to fight to control landing beaches for the assault on Okinawa phase

Continues

Okinawa A.9.0.1

A.9.0.1 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to control landing beaches for the assault on Okinawa phase

What is the overall military force to be used by Japan_1945 for the assault on Okinawa phase that is capable of the action interdict US_1945 landing craft?

Japanese_Forces_Okinawa

Determine if Japanese_Forces_Okinawa are capable of the action control landing beaches

Is Japanese_Forces_Okinawa capable of the action control landing beaches?

No because an inadequate portion of Japanese_Forces_Okinawa is positioned to control the operationally significant land area landing beaches

Japanese_Forces_Okinawa is not an enemy operational COG candidate for US_1945 based on the capability to control landing beaches for the assault on Okinawa phase

Okinawa A.10.0.1

A.10.0.1 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to control landing beaches for the assault on Okinawa phase

What capabilities (besides military force) provide Japan_1945 the physical strength to control landing beaches?

Concentrate forces in theater of operations (landing beaches)

Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to concentrate forces at landing beaches to control landing beaches for the assault on Okinawa phase

How can Japan_1945 concentrate forces at landing beaches to control landing beaches?

Concentrate two divisions at the site of the main US_1945 landing

Japanese concentration of two divisions at the site of the main US_1945 landing is an enemy operational COG candidate for US_1945 for the assault on Okinawa phase

Test the Japanese concentration of two divisions at the site of the main US_1945 landing as an enemy operational COG for US_1945 for the assault on Okinawa phase

Would the defeat of the capability to concentrate two divisions at the site of the main US landing directly enable US_1945 to establish a foothold on Okinawa?

Yes because the most direct threat to gaining a foothold on Okinawa would be eliminated

Japanese concentration of two divisions at the site of the main US_1945 landing is a viable enemy operational COG for US_1945 for the assault on Okinawa phase

Okinawa A.11.0.0.1

A.11.0.0.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to control landing beaches for the assault on Okinawa phase

What sources of strength provide Japan_1945 the freedom of action to control landing beaches?

None

No friendly operational COG candidates found among sources of strength that provide Japan_1945 the freedom of action to control landing beaches for the assault on Okinawa phase

Okinawa A.11.0.1.1

A.11.0.1.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the will to fight to control landing beaches for the assault on Okinawa phase

What sources of strength provide Japan_1945 the will to fight to control landing beaches?

None

No friendly operational COG candidates found among sources of strength that provide Japan_1945 the will to fight to control landing beaches for the assault on Okinawa phase

Okinawa G.3.0

G.3.0 Identify and test operational COG candidates for US_1945 for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

What are the operational aims of US_1945 in the ground campaign on Okinawa phase?

Seize Okinawa

Identify and test operational COG candidates for US_1945 relative to the operational aim seize Okinawa for the ground campaign on Okinawa phase

What operational actions by US_1945 are required to accomplish the aim seize Okinawa?

Conduct offensive operations in theater (Okinawa)

- **G.4.0** Identify and test friendly operational COG candidates for US_1945 from among the sources of strength that enable US_1945 to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

  Continues

- **G.8.0** Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that US_1945 could defeat in order to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

  Continues

Okinawa G.4.0

G.4.0 Identify and test friendly operational COG candidates for US_1945 from among the sources of strength that enable US_1945 to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

What are the sources of strength that provide US_1945 the capability to conduct offensive operations to seize Okinawa?

I consider forces that provide the physical strength to conduct the operation

G.5.0 Identify and test friendly operational COG candidates for US_1945 from among the forces that provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

I consider other capabilities that provide the physical strength to conduct the operation

G.6.0 Identify and test friendly operational COG candidates for US_1945 from among the operational capabilities that provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

I consider sources of strength that provide the freedom of action to conduct the operation

G.7.0.0 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the freedom of action to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

I consider sources of strength that provide US_1945 the will to fight to conduct the operation

G.7.0.1 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the will to fight to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

Okinawa G.5.0

G.5.0 Identify and test friendly operational COG candidates for US_1945 from among the forces that provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

What is the overall military force to be used by US_1945 for the ground campaign on Okinawa phase that is capable of the action conduct offensive operations?

TF56_Expeditionary_Troops

TF56_Expeditionary_Troops is a friendly operational COG candidate for US_1945 for the ground campaign on Okinawa phase

G.5.1 Test for more focused centers of gravity among the sub-groupings of TF56_Expeditionary_Troops capable of conducting offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

G.5.3 Choose Japanese_Forces_Okinawa if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

TF56_Expeditionary_Troops is a viable friendly operational COG for US_1945 based on the capability to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.5.1

G.5.1 Test for more focused centers of gravity among the sub-groupings of TF56_Expeditionary_Troops capable of conducting offensive operations to seize Okinawa for the ground campaign on Okinawa phase

What further subordinate or local force grouping(s) within this force are capable of the action conduct offensive operations for the ground campaign on Okinawa phase to achieve the aim seize Okinawa?

III_Amphibious_Corps

G.5.2.0 Test whether III_ Amphibious_Corps is a friendly operational COG as a military force to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

XXIV_Corps

G.5.2.1 Test whether XXIV_Corps is a friendly operational COG as a military force to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Continues

Okinawa G.5.2.0

Test whether III_ Amphibious_Corps is a friendly operational COG as a military force to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Would the defeat of the III_ Amphibious_Corps capability to conduct offensive operations prevent US_1945 from seizing Okinawa?

No because XXIV_Corps also has this capability

III_ Amphibious_Corps is not a viable friendly operational COG for US_1945 based on the capability to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.5.2.1

Test whether XXIV_Corps is a friendly operational COG as a military force to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Would the defeat of the XXIV_Corps capability to conduct offensive operations prevent US_1945 from seizing Okinawa?

No because III_Corps also has this capability

XXIV_Corps is not a friendly operational COG candidate for US_1945 based on the capability to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.6.0

G.6.0 Identify and test friendly operational COG candidates for US_1945 from among the operational capabilities that provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

What capabilities (besides military force) provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase?

None

No friendly operational COG candidates found among capabilities (besides military force) that provide US_1945 the physical strength to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.7.0.0

G.7.0.0 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the freedom of action to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

What sources of strength provide US_1945 the freedom of action to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase?

None

No friendly operational COG candidates found among sources of strength that provide US_1945 the freedom of action to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.7.0.1

G.7.0.1 Identify and test friendly operational COG candidates for US_1945 from among the other sources of strength that provide US_1945 the will to fight to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

What sources of strength provide US_1945 the will to fight to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase?

None

No friendly operational COG candidates found among sources of strength that provide US_1945 the will to fight to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase

Okinawa G.8.0

G.8.0 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that US_1945 could defeat in order to conduct offensive operations to seize Okinawa for the ground campaign on Okinawa phase of the Okinawa_1945 scenario

What operational actions by Japan_1945 are capable of opposing US_1945 operations to conduct offensive operations to seize Okinawa?

Conduct defensive operations in theater (Okinawa)

G.8.1 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Continues

Okinawa G.8.1

G.8.1 Identify and test enemy operational COG candidates for US_1945 from among the sources of strength that provide Japan_1945 the capability to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

What are the sources of strength that Japan_1945 possesses to conduct defensive operations on Okinawa?

I consider forces that provide the physical strength to oppose the operation

G.9.0 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Continues

I consider other capabilities that provide the physical strength to oppose the operation

G.10.0 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Continues

I consider sources of strength that provide the freedom of action to oppose the operation

G.11.0.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Continues

I consider sources of strength that provide the will to fight to oppose the operation

G.11.0.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the will to fight to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Continues

Okinawa G.9.0

G.9.0 Identify and test enemy operational COG candidates for US_1945 from among the forces that provide Japan_1945 the physical strength to conduct defensive operations on Okinawa

What is the overall military force to be used by Japan_1945 for the ground campaign on Okinawa phase that is capable of the action conduct defensive operations?

32_Army

32_Army is an enemy operational COG candidate for US_1945 for the ground campaign on Okinawa phase

G.9.1 Test for more focused centers of gravity among the sub-groupings of 32_Army capable of conducting defensive operations for the ground campaign on Okinawa phase

Continues

G.9.3 Choose 32_Army if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

32_Army is a viable friendly operational COG for US_1945 based on the capability to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

Okinawa G.9.1

G.9.1 Test for more focused centers of gravity among the sub-groupings of 32_Army capable of conducting defensive operations for the ground campaign on Okinawa phase

What further subordinate or local force grouping(s) within this force are capable of the action conduct defensive operations for the ground campaign on Okinawa phase to achieve the aim oppose US_1945 operations to seize Okinawa?

62_Div_on_central_Shimajiri_isthmus

G.9.2.0 Test whether 62_Div_on_central_Shimajiri_isthmus is an enemy operational COG as a military force to conduct offensive operations for the ground campaign on Okinawa phase

Continues

24_Div_and_44_IMB_on_southern_Okinawa

G.9.2.1 Test whether 24_Div_and_44_IMB_on_southern_Okinawa is an enemy operational COG as a military force to conduct offensive operations for the ground campaign on Okinawa phase

Continues

Okinawa G.9.2.0

Test whether 62_Div_on_central_Shimajiri_isthmus is an enemy operational COG as a military force to conduct offensive operations for the ground campaign on Okinawa phase

Would the defeat of the 62_Div_on_central_ Shimajiri_isthmus capability to conduct defensive operations directly enable US_1945 to seize Okinawa?

No because the defeat of this force does not lead to the defeat of remaining 32_Army forces defending Okinawa

62_Div_on_central_Shimajiri_isthmus is not a viable enemy operational COG for US_1945 based on the capability to conduct defensive operations for the ground campaign on Okinawa phase

Okinawa G.9.2.1

Test whether 24_Div_and_44_IMB_on_southern_Okinawa is an enemy operational COG as a military force to conduct offensive operations for the ground campaign on Okinawa phase

Would the defeat of the 24_Div_and_44_IMB_on_southern_Okinawa capability to conduct defensive operations directly enable US_1945 to seize Okinawa?

No because the defeat of this force does not lead to the defeat of remaining 32_Army forces defending Okinawa

24_Div_and_44_IMB_on_southern_Okinawa is not a viable enemy operational COG for US_1945 based on the capability to conduct defensive operations for the ground campaign on Okinawa phase

Okinawa G.10.0

G.10.0 Identify and test enemy operational COG candidates for US_1945 from among the operational capabilities that provide Japan_1945 the physical strength to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

What capabilities (besides military force) provide Japan_1945 the physical strength to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase?

None

No enemy operational COG candidates found among capabilities (besides military force) that provide Japan_1945 the physical strength to conduct defensive operations for the ground campaign on Okinawa phase

Okinawa G.11.0.0

G.11.0.0 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

What sources of strength provide Japan_1945 the freedom of action to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase?

None

No enemy operational COG candidates found among sources of strength that provide Japan Japan_1945 the freedom of action to conduct defensive operations for the ground campaign on Okinawa phase

Okinawa G.11.0.1

G.11.0.1 Identify and test enemy operational COG candidates for US_1945 from among the other sources of strength that provide Japan_1945 the freedom of action to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase

What sources of strength provide Japan _1945 the will to fight to conduct defensive operations on Okinawa for the ground campaign on Okinawa phase?

None

No enemy operational COG candidates found among sources of strength that provide Japan_1945 the will to fight to conduct defensive operations for the ground campaign on Okinawa phase

APPENDIX C

MODELING FOR PANAMA CASE STUDY

This appendix contains the task reduction modeling generated for the Panama scenario using the general model (appendix A). This modeling is explained in detail in chapter 4. The modeling conventions are those explained in chapter 3 and shown in appendix A. Modeling steps have been indexed to correspond to thode in the general model for the readability of the model and for ease of comparison between models. Modeling here is not repeated by phase, so there is no prefixing of index numbers as in Okinawa (appendix B). Where modeling continues to another page, the continuation can be found by referencing the index number of the current task and finding that modeling step.

Panama 1.0

1.0 Identify and test operational COG candidates for the Panama_1989 scenario

What kind of scenario is Panama_1989?

Panama_1989 is a conventional war scenario

Identify and test operational COG candidates for Panama_1989 which is a major theater of war scenario

What are the opposing forces in the Panama_1989 scenario?

US_1989

2.0 Identify and test operational COG candidates for US_1989

Continues

Panama_1989

Identify and test operational COG candidates for Panama_1989

Not modeled

Panama 2.0

2.0 Identify and test operational COG candidates for US_1989

Is US_1989 a single-member force or a multi-member force?

US_1989 is a single-member force

Identify and test operational COG candidates for US_1989, a single-member force

What are the phases of the Panama_1989 scenario for US_1989?

There are no distinct phases for the purpose of COG analysis

3.0 Identify and test operational COG candidates for US_1989 for the Panama_1989 scenario

Continues

Panama 3.0

3.0 Identify and test operational COG candidates for US_1989 for the Panama_1989 scenario

What are the operational aims of US_1989 in the Panama_1989 scenario*?*

Disarm and dismantle the PDF

Identify and test operational COG candidates for US_1989 relative to the operational aim disarm and dismantle the PDF for the Panama_1989 scenario

What operational actions by US_1989 are required to accomplish the aim disarm and dismantle the PDF?

Conduct offensive operations in theater (Panama)

4.0 Identify and test friendly operational COG candidates for US_1989 from among the sources of strength that enable US_1989 to conduct offensive operations to disarm and dismantle the PDF for the Panama_1989 scenario

Continues

8.0 Identify and test enemy operational COG candidates for US_1989 from among the sources of strength that US_1989 could defeat in order to conduct offensive operations to disarm and dismantle the PDF for the Panama_1989 scenario

Continues

Panama 4.0

4.0 Identify and test friendly operational COG candidates for US_1989 from among the sources of strength that enable US_1989 to conduct offensive operations to disarm and dismantle the PDF for the Panama_1989 scenario

What are the sources of strength that provide US_1989 the capability to conduct offensive operations to disarm and dismantle the PDF?

I consider forces that provide the physical strength to conduct the operation

5.0 Identify and test friendly operational COG candidates for US_1989 from among the forces that provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF

Continues

I consider other capabilities that provide the physical strength to conduct the operation

6.0 Identify and test friendly operational COG candidates for US_1989 from among the operational capabilities that provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF

Continues

I consider sources of strength that provide the freedom of action to conduct the operation

7.0.0 Identify and test friendly operational COG candidates for US_1989 from among the other sources of strength that provide US_1989 the freedom of action to conduct offensive operations to disarm and dismantle the PDF

Continues

I consider sources of strength that provide the will to fight to conduct the operation

7.0.1 Identify and test friendly operational COG candidates for US_1989 from among the other sources of strength that provide US_1989 the will to fight to conduct offensive operations to disarm and dismantle the PDF

Continues

Panama 5.0

5.0 Identify and test friendly operational COG candidates for US_1989 from among the forces that provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF

What is the overall military force to be used by US_1989 in the Panama_1989 scenario?

JTF_South

Determine if JTF_South is capable of the action conduct offensive operations

Is JTF_South capable of the action conduct offensive operations?

Yes because it is organized with ground and amphibious support forces

JTF_South is a friendly operational COG candidate for US_1989

5.1.0 Test for more focused centers of gravity among the sub-groupings of JTF_South capable of conducting offensive operations to disarm and dismantle the PDF

Continues

5.3.0 Choose JTF_South if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

Yes, Assault_Forces is a viable COG

JTF_South is not the most focused choice for a friendly operational COG for US_1989 based on the capability to conduct offensive operations to disarm and dismantle the PDF

Panama 5.1.0

5.1.0 Test for more focused centers of gravity among the sub-groupings of JTF_South capable of conducting offensive operations to disarm and dismantle the PDF

What further subordinate or local force grouping(s) within this force are capable of the action conduct offensive operations to achieve the aim disarm and dismantle the PDF?

- *Assault_Forces*
  - Assault_Forces is a friendly operational COG candidate for US_1989
  - **5.2.0** Test whether Assault_Forces is a friendly operational COG as a military force to conduct offensive operations to disarm and dismantle the PDF

    Continues

- *In_Country_Forces*
  - In_Country_Forces is a friendly operational COG candidate for US_1989
  - **5.2.1** Test whether In_Country_Forces is a friendly operational COG as a military force to conduct offensive operations to disarm and dismantle the PDF

    Continues

Panama 5.2.0

5.2.0 Test whether Assault_Forces is a friendly operational COG as a military force to conduct offensive operations to disarm and dismantle the PDF

Would the defeat of the Assault_Forces capability to Conduct offensive operations prevent US_1989 from disarming and dismantling the PDF ?

Yes because the remaining US_1989 forces in country cannot conduct offensive with sufficient speed and surprise to accomplish the aim disarm and dismantle the PDF

5.1.1 Test for more focused centers of gravity among the sub-groupings of Assault_Forces capable of conducting offensive operations to disarm and dismantle the PDF

Continues

5.3.1 Choose Assault_Forces if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

Assault_Forces is a viable friendly operational COG for US_1989 based on the capability to conduct offensive operations to disarm and dismantle the PDF

Panama 5.1.1

5.1.1 Test for more focused centers of gravity among the sub-groupings of Assault_Forces capable of conducting offensive operations to disarm and dismantle the PDF

What further subordinate or local force grouping(s) within this force are capable of the action conduct offensive operations to disarm and dismantle the PDF?

None, the PDF objectives are too dispersed for any subordinate force to accomplish the overall purpose

No further COG candidates evaluated from here

Panama 5.2.1

5.2.1 Test whether In_Country_Forces is a friendly operational COG as a military force to conduct offensive operations to disarm and dismantle the PDF

Would the defeat of the In_Country_Forces capability to Conduct offensive operations prevent US_1989 from disarming and dismantling the PDF ?

No because Assault_Forces still have adequate combat to conduct offensive with sufficient speed and surprise to accomplish the aim disarm and dismantle the PDF

In_Country_Forces is not a friendly operational COG candidate for US_1989 based on the capability to conduct offensive operations to disarm and dismantle the PDF

Panama 6.0

6.0 Identify and test friendly operational COG candidates for US_1989 from among the operational capabilities that provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF

What capabilities (besides military force) provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF?

None

No friendly operational COG candidates found among capabilities (besides military force) that provide US_1989 the physical strength to conduct offensive operations to disarm and dismantle the PDF

Panama 7.0.0

7.0.0 Identify and test friendly operational COG candidates for US_1989 from among the other sources of strength that provide US_1989 the freedom of action to conduct offensive operations to disarm and dismantle the PDF

What sources of strength provide US_1989 the freedom of action to conduct offensive operations to disarm and dismantle the PDF?

None

No friendly operational COG candidates found among sources of strength that provide US_1989 the freedom of action to conduct offensive operations to disarm and dismantle the PDF

Panama 7.0.1

7.0.1 Identify and test friendly operational COG candidates for US_1989 from among the other sources of strength that provide US_1989 the will to fight to conduct offensive operations to disarm and dismantle the PDF

What sources of strength provide US_1989 the will to fight to conduct offensive operations to disarm and dismantle the PDF?

None

No friendly operational COG candidates found among sources of strength that provide US_1989 the will to fight to conduct offensive operations to disarm and dismantle the PDF

Panama 8.0

8.0 Identify and test enemy operational COG candidates for US_1989 from among the sources of strength that US_1989 could defeat in order to conduct offensive operations to disarm and dismantle the PDF in the Panama_1989 scenario

What operational actions by Panama_1989 are capable of opposing US_1989 operations to conduct offensive operations to disarm and dismantle the PDF ?

Conduct defensive operations in theater (Panama)

8.1 Identify and test enemy operational COG candidates for US_1989 from among the sources of strength that provide Panama_1989 the capability to conduct defensive operations on Panama

Continues

Panama 8.1

8.1 Identify and test enemy operational COG candidates for US_1989 from among the sources of strength that provide Panama_1989 the capability to conduct defensive operations on Panama

What are the sources of strength that Panama_1989 possesses to conduct defensive operations on Panama ?

I consider forces that provide the physical strength to oppose the operation

9.0 Identify and test enemy operational COG candidates for US_1989 from among the forces that provide Panama_1989 the physical strength to conduct defensive operations on Panama

Continues

I consider other capabilities that provide the physical strength to oppose the operation

10.0 Identify and test enemy operational COG candidates for US_1989 from among the operational capabilities that provide Panama_1989 the physical strength to conduct defensive operations on Panama

Continues

I consider sources of strength that provide the freedom of action to oppose the operation

11.0.0 Identify and test enemy operational COG candidates for US_1989 from among the other sources of strength that provide Panama_1989 the freedom of action to conduct defensive operations on Panama

Continues

I consider sources of strength that provide the will to fight to oppose the operation

11.0.1 Identify and test enemy operational COG candidates for US_1989 from among the other sources of strength that provide Panama_1989 the will to fight to conduct defensive operations on Panama

Continues

Panama 9.0

9.0 Identify and test enemy operational COG candidates for US_1989 from among the forces that provide Panama_1989 the physical strength to conduct defensive operations on Panama

What is the overall military force to be used by Panama_1989 that is capable of the action conduct defensive operations?

PDF

Determine if PDF is capable of the action conduct defensive operations on Panama

Is PDF capable of the action conduct defensive operations?

Yes because it is organized with widely dispersed infantry companies and battalions throughout the areas to be assaulted by US_1989

PDF is an enemy operational COG candidate for US_1989

9.1 Test for more focused centers of gravity among the sub-groupings of PDF capable of conducting defensive operations on Panama

Continues

9.3 Choose PDF if a center of gravity is not identified among the subordinate or local force grouping(s) within this force

Was a more focused center of gravity identified among the subordinate or local force grouping(s) within this force?

No

PDF is a viable enemy operational COG for US_1989 based on the capability to conduct defensive operations on Panama

Panama 9.1

9.1 Test for more focused centers of gravity among the sub-groupings of PDF capable of conducting defensive operations on Panama

What further subordinate or local force grouping(s) within this force are capable of the action conduct defensive operations to achieve the aim oppose US_1989 operations to disarm and dismantle the PDF ?

None, all of the subordinate units are too small and dispersed to effectively oppose US_1989

No further COG candidates evaluated from here

Panama 10.0

10.0 Identify and test enemy operational COG candidates for US_1989 from among the operational capabilities that provide Panama_1989 the physical strength to conduct defensive operations on Panama

What capabilities (besides military force) provide Panama_1989 the physical strength to conduct defensive operations on Panama ?

None

No enemy operational COG candidates found among capabilities (besides military force) that provide Panama_1989 the physical strength to conduct defensive operations on Panama

Panama 11.0.0

11.0.0 Identify and test enemy operational COG candidates for US_1989 from among the other sources of strength that provide Panama_1989 the freedom of action to conduct defensive operations on Panama

What does Panama_1989 do to maintain the freedom of action to conduct defensive operations on Panama?

Protecting the PDF headquarters allowing the centralized command and control of the PDF

11.1.0 Identify and test enemy operational COG candidates for US_1989 from among Panama_1989 sources of strength capable of providing freedom of action by protecting the PDF headquarters allowing the centralized command and control of the PDF

What Panama_1989 source of strength is capable of protecting the PDF headquarters allowing the centralized command and control of the PDF

Commandancia_Forces

Commandancia_Forces is an enemy operational COG candidate for US_1989 because it provides freedom of action by protecting the PDF headquarters allowing the centralized command and control of the PDF

11.2.0 Test the Commandancia_Forces as an enemy operational COG for US_1989 capable of providing Panama_1989 freedom of action by protecting the PDF headquarters allowing the centralized command and control of the PDF

Would the defeat of the Commandancia_Forces capability to provide freedom of action by protecting the PDF headquarters allowing the centralized command and control of the PDF directly enable US_1989 to disarm and dismantle the PDF?

Yes because the loss of centralized control would cause the PDF units to become isolated and ineffective against US_1989 forces

Commandancia_Forces is a viable enemy operational COG for US_1989 because it provides freedom of action to Panama_1989 by protecting the PDF headquarters allowing the centralized command and control of the PDF

Panama 11.0.1

11.0.1 Identify and test enemy operational COG candidates for US_1989 from among the other sources of strength that provide Panama_1989 the will to fight to conduct defensive operations on Panama

What does Panama_1989 do to maintain the will to fight to conduct defensive operations on Panama?

Maintaining Noriega's control over the PDF

11.1.1 Identify and test enemy operational COG candidates for US_1989 from among Panama_1989 sources of strength capable of maintaining Noriega's control over the PDF

What Panama_1989 source of strength is capable of maintaining Noriega's control over the PDF?

6th_and_7th_Rifle_Companies_at_Rio_Hato

6th_and_7th_Rifle_Companies_at_Rio_Hato is an enemy operational COG candidate for US_1989 because it provides will to fight by maintaining Noriega's control over the PDF

11.2.1 Test the 6th_and_7th_Rifle_Companies_at_Rio_Hato as an enemy operational COG for US_1989 capable of providing Panama_1989 will to fight by maintaining Noriega's control over the PDF

Would the defeat of the 6th_and_7th_Rifle_Companies_at_Rio_Hato capability to provide will to fight by maintaining Noriega's control of the PDF directly enable US_1989 to disarm and dismantle the PDF?

Yes because the loss of this loyal and capable unit would expose Noriega to capture and cause the remainder of the PDF to become demoralized

6th_and_7th_Rifle_Companies_at_Rio_Hato is a viable enemy operational COG for US_1989 because it provides will to fight to Panama_1989 by maintaining Noriega's control over the PDF

APPENDIX D

EVALUATION INSTRUMENTS

This appendix contains the instruments used for expert evaluation of the results of modeling. Two documents are included here: the instrument for the results of the Okinawa analysis and the one for the Panama analysis. The use of the instruments in the research methodology is explained in chapter 3, in the section, “Evaluation of Results.” The data gathered from these instruments are at appendix E, and the analysis of the data is presented in chapter 4 in the section, “Results of Expert Evaluation.”

US WWII campaign in Okinawa, 1945

Name ____________________________ Date _______________

Office ____________________________

Phone ____________________________

Purpose

You have been selected to evaluate center of gravity analysis for an historical scenario based on your expertise in operational art. Your evaluation will support analysis of the results obtained in research regarding the determination of operational centers of gravity in support of an MMAS thesis. The results of your evaluation will be combined with those of other evaluators to form a baseline of expert opinion regarding evaluation.

Thank you for your support of this work.

Instructions

Please evaluate the analysis that follows according to:

- The identification of candidates considered as centers of gravity (note that a "candidate" in this analysis is something considered as a center of gravity, which is either accepted or rejected based on further analysis).
- The selection of "valid" centers of gravity from among those candidates and their rationale.
- The elimination of inappropriate centers of gravity from among candidates.
- The appropriateness of the rationale used throughout for identifying candidates and accepting/rejecting them as centers of gravity

First respond to the background questions, and then read the following sections, responding to questions as they occur in each section:

I. Questions about your background
II. Scenario Background
III. Individual Center of Gravity Candidates and Selections
IV. Overall Center of Gravity Analysis
V. Comments

Please note that you may comment on any response (please put them in *Section V*) but such comments are strictly optional.

I. Questions about your background

1. What is your military background?

Service _______________ Years of service ____

☐ Active ☐ Retired since ____________

Rank _________

2. Do you have any experience teaching the center of gravity concept?

☐ No experience teaching center of gravity

☐ Taught center of gravity at:

SSC level	______ Years	Comments ________________________
CGSC level	______ Years	Comments ________________________
Other	______ Years	Comments ________________________

Please respond to the following questions regarding your familiarity with center of gravity:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

3. I am familiar with the concept of center of gravity.	1 2 3 4 5
4. I consider myself qualified to determine operational centers of gravity.	1 2 3 4 5

II. Scenario Background

This center of gravity analysis is for the US WWII campaign in Okinawa, 1945.

(Review the attached synopsis of the Okinawa Campaign as necessary)

Please respond to the following questions regarding the scenario:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

5. I am familiar with this campaign.	1 2 3 4 5
6. I consider myself qualified to determine operational centers of gravity regarding this campaign.	1 2 3 4 5
7. I have already formed opinions about operational center(s) of gravity for this campaign.	1 2 3 4 5

III. Individual Center of Gravity Candidates and Selections

Please read the following analysis and respond to questions as they occur:

I considered both friendly and enemy centers of gravity for the scenario. I considered these from the perspective of the US forces in that scenario. That is, the analysis is done according to the operational aims of the US in the scenario. A “friendly” center of gravity is a US center of gravity to be protected by the US, and an “enemy” center of gravity is a Japanese center of gravity to be defeated by the US.

I considered centers of gravity related to two phases that are relevant to analyzing centers of gravity for the US operation in Okinawa--the assault phase and the ground operations phase. I analyzed centers of gravity separately for each phase.

Assault Phase

I considered Establish a foothold on Okinawa to be the operational aim of the US for this phase. I considered Conduct amphibious forcible entry to be an action that the US could take to accomplish that aim.

Friendly centers of gravity (operational level) for this phase

I considered the forces available to the US to accomplish the action Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I consider the following forces to be sufficiently capable of performing the action conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity:

TF51 (Joint Expeditionary Force) is a candidate because it is the overall military force to be used by US during the assault on Okinawa phase and is capable of the action conduct amphibious forcible entry.

This candidate is NOT viable as a center of gravity choice in this situation. Although the defeat of its capability to conduct amphibious forcible entry would prevent US from establishing a foothold on Okinawa, a subordinate grouping of forces within this force, Main Landing Forces, was found to be a more focused center of gravity capable of this action.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

8. I agree that this is NOT a valid center of gravity for this scenario.	1	2	3	4	5	
9. The rationale presented for rejecting this center of gravity is valid.	1	2	3	4	5	
10. I have a different reason for rejecting this as a center of gravity.	1	2	3	4	5	N/A

Main Landing Forces (assigned to assault Hagushi Beaches) is a candidate because it is a subordinate or local force grouping within TF51 (Joint Expeditionary Force) capable of the action conduct amphibious forcible entry during the assault on Okinawa phase to achieve the aim establish a foothold on Okinawa

This candidate is a viable center of gravity choice because the defeat of its capability to conduct amphibious forcible entry could prevent US from establishing a foothold on Okinawa since there would not be enough remaining forces with this capability to accomplish the aim, and no further subordinate grouping of forces within Main Landing Forces was found to be a more focused center of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

11. I agree that this is a valid center of gravity for this scenario.	1 2 3 4 5
12. The rationale presented for choosing this center of gravity is valid.	1 2 3 4 5
13. I have a different reason for choosing this as a center of gravity.	1 2 3 4 5 N/A

<u>TF53 (Northern Attack Force)</u> is a candidate because it is a subordinate or local force grouping within Main Landing Forces capable of the action conduct amphibious forcible entry during the assault on Okinawa phase to achieve the aim establish a foothold on Okinawa.

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct amphibious forcible entry would not prevent US from establishing a foothold on Okinawa, since TF55 (Southern Attack Force) would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

14. I agree that this is NOT a valid center of gravity for this scenario.	1 2 3 4 5
15. The rationale presented for rejecting this center of gravity is valid.	1 2 3 4 5
16. I have a different reason for rejecting this as a center of gravity.	1 2 3 4 5 N/A

<u>TF55 (Southern Attack Force)</u> is a candidate because it is a subordinate or local force grouping within Main Landing Forces capable of the action conduct amphibious forcible entry during the assault on Okinawa phase to achieve the aim establish a foothold on Okinawa.

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct amphibious forcible entry would not prevent US from establishing a foothold on Okinawa, since TF53 (Northern Attack Force) would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

17. I agree that this is NOT a valid center of gravity for this scenario.	1 2 3 4 5
18. The rationale presented for rejecting this center of gravity is valid.	1 2 3 4 5
19. I have a different reason for rejecting this as a center of	1 2 3 4 5 N/A

gravity.

I considered capabilities (besides military force) available to the US to accomplish the action Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no capabilities to be a source of strength capable of sufficiently performing the action Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

20. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide the US the freedom of action to accomplish the action Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no sources of strength that sufficiently provide freedom of action to Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

21. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide the US the will to fight to accomplish the action Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no sources of strength that sufficiently provide will to fight to Conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

22. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

Enemy centers of gravity (operational level) for this phase

I considered opposing US operations to conduct amphibious forcible entry to establish a foothold on Okinawa to be the operational aim of Japan for this phase. I considered Interdict operational forces/targets (US_1945 landing forces) and Control operationally significant land area (landing beaches) to be actions that Japan could take to accomplish that aim.

I considered the forces available to Japan to accomplish the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa.

Result: I consider the following forces to be sufficiently capable of performing the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity:

Japanese Forces Okinawa is a candidate because it is the overall military force to be used by Japan during the assault on Okinawa phase and is capable of the action interdict operational forces/targets (US_1945 landing forces).

This candidate is NOT viable as a center of gravity choice in this situation. It is not capable of the action control landing beaches because an inadequate portion of this force is positioned to control the operationally significant land area in the vicinity of the beaches. Although it is capable of the action interdict operational forces/targets (US_1945 landing forces), and the defeat of that capability would allow US to establish a foothold on Okinawa, a subordinate grouping of forces within this force, Japanese Air Forces, was found to be a more focused center of gravity capable of that action.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

23. I agree that this is NOT a valid center of gravity for this scenario.	1	2	3	4	5	
24. The rationale presented for rejecting this center of gravity is valid.	1	2	3	4	5	
25. I have a different reason for rejecting this as a center of gravity.	1	2	3	4	5	N/A

Japanese Air Forces (including Kamikaze) is a candidate because it is a subordinate or local force grouping within Japanese Forces Okinawa capable of the action interdict operational forces/targets (US_1945 landing forces) during the ground campaign on Okinawa phase to achieve the aim oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa.

This candidate is a viable center of gravity choice because the defeat of the Japanese Air Forces capability to interdict US landing forces would directly enable US to establish a foothold on Okinawa because Japanese aircraft pose the most significant threat to forces on beaches and afloat, and no further subordinate grouping of forces within Japanese Air Forces was found to be a more focused center of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

26. I agree that this is a valid center of gravity for this scenario.	1	2	3	4	5	
27. The rationale presented for choosing this center of gravity is valid.	1	2	3	4	5	
28. I have a different reason for choosing this as a center of gravity.	1	2	3	4	5	N/A

I considered capabilities (besides military force) available to Japan to accomplish the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa.

Result: I consider the following capability to be sufficiently capable of performing the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity:

The capability to concentrate two divisions at the site of the main US landing is a candidate because it is an operational capability that provides Japan the ability to concentrate forces in theater of operations to control landing beaches.

This candidate is a viable center of gravity choice because the defeat of the capability to concentrate two divisions at the site of the main US landing would directly enable US to establish a foothold on Okinawa because the most immediate threat to gaining a foothold on Okinawa would be eliminated.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

29. I agree that this is a valid center of gravity for this scenario.	1	2	3	4	5	
30. The rationale presented for choosing this center of gravity is valid.	1	2	3	4	5	
31. I have a different reason for choosing this as a center of gravity.	1	2	3	4	5	N/A

I considered sources of strength that provide Japan the freedom of action to accomplish the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no sources of strength that sufficiently provide freedom of action to oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

32. I agree that no center of gravity candidates of this type should be considered in this situation.	1	2	3	4	5

I considered sources of strength that provide the Japan the will to fight to accomplish the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no sources of strength that sufficiently provide will to fight to oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

33. I agree that no center of gravity candidates of this type should be considered in this situation.	1	2	3	4	5

Ground Operations Phase

I next analyzed centers of gravity relative to the ground operations phase.

Friendly centers of gravity (operational level) for this phase

I considered Seize Okinawa to be the operational aim of the US for this phase and I considered the sources of strength that could enable the US to accomplish that aim.

I considered Conduct offensive operations in theater (Okinawa) to be an action that the US could take to accomplish the aim seize Okinawa.

I considered the forces available to the US to accomplish the action Conduct offensive operations to seize Okinawa in the ground operations phase.

Result: I consider the following forces to be sufficiently capable of performing the action conduct offensive operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity:

TF56 (Expeditionary Troops) is a candidate because it is the overall military force to be used by US during the ground operations phase and is capable of the action conduct offensive operations to seize Okinawa.

This candidate is a viable center of gravity choice because the defeat of its capability to conduct offensive operations could prevent US from seizing Okinawa since there would not be enough remaining forces with this capability to accomplish the aim, and no further subordinate grouping of forces within TF56 (Expeditionary Troops) was found to be a more focused center of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

34. This is a valid center of gravity for this scenario.	1	2	3	4	5	
35. The rationale presented for choosing this center of gravity is valid.	1	2	3	4	5	
36. I have a different reason for choosing this as a center of gravity.	1	2	3	4	5	N/A

III Amphibious Corps is a candidate because it is a subordinate or local force grouping within TF56 (Expeditionary Troops) capable of the action conduct offensive operations during the ground operations phase to achieve the aim seize Okinawa.

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct offensive operations would not prevent US from seizing Okinawa, since XXIV Corps would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

37. This is NOT a valid center of gravity for this scenario.	1	2	3	4	5	
38. The rationale presented for rejecting this center of gravity is valid.	1	2	3	4	5	
39. I have a different reason for rejecting this as a center of gravity.	1	2	3	4	5	N/A

XXIV Corps is a candidate because it is a subordinate or local force grouping within TF56 (Expeditionary Troops) capable of the action conduct offensive operations during the ground operations phase to achieve the aim seize Okinawa.

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct offensive operations would not prevent US from seizing Okinawa, since III Amphibious Corps would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

40. This is NOT a valid center of gravity for this scenario. 1 2 3 4 5

41. The rationale presented for rejecting this center of gravity is valid. 1 2 3 4 5

42. I have a different reason for rejecting this as a center of gravity. 1 2 3 4 5 N/A

I considered capabilities (besides military force) available to the US to accomplish the action Conduct offensive operations to seize Okinawa in the ground operations phase.

Result: I found no capabilities to be a source of strength capable of sufficiently performing the action Conduct offensive operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

43. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide the US the freedom of action to accomplish the action Conduct offensive operations to seize Okinawa in the ground operations phase.

Result: I found no sources of strength that sufficiently provide freedom of action to Conduct offensive operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

44. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide the US the will to fight to accomplish the action Conduct offensive operations to seize Okinawa in the ground operations phase.

Result: I found no sources of strength that sufficiently provide will to fight to Conduct offensive operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

45. I agree that no center of gravity candidates of this type should be considered in this situation.	1 2 3 4 5

Enemy centers of gravity (operational level) for this phase

I considered opposing US operations to seize Okinawa during the ground campaign on Okinawa phase to be the operational aim of Japan for this phase. I considered Conduct defensive operations in theater (Okinawa) to be then action that Japan could take to accomplish that aim.

I considered the forces available to Japan to accomplish the action oppose US operations to seize Okinawa.

Result: I consider the following forces to be sufficiently capable of performing the action oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity:

32 Army is a candidate because it is the overall military force to be used by Japan during the ground operations on Okinawa phase and is capable of the action conduct defensive operations in theater (Okinawa).

This candidate is a viable center of gravity choice because the defeat of its capability to conduct defensive operations could enable US to seize Okinawa since it is the overall source of forces for this purpose and there would not be any remaining forces with this capability to accomplish the aim, and no further subordinate grouping of forces within 32 Army was found to be a more focused center of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

46. This is a valid center of gravity for this scenario.	1 2 3 4 5
47. The rationale presented for choosing this center of gravity is valid.	1 2 3 4 5
48. I have a different reason for choosing this as a center of gravity.	1 2 3 4 5 N/A

62 Div (on central Shimajiri isthmus) is a candidate because it is a subordinate or local force grouping within 32 Army capable of the action conduct defensive operations in theater (Okinawa).

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct defensive operations would not enable US to seize Okinawa, since 24 Div and 44 IMB (on southern Okinawa) would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

49. This is NOT a valid center of gravity for this scenario.	1 2 3 4 5
50. The rationale presented for rejecting this center of gravity is valid.	1 2 3 4 5
51. I have a different reason for rejecting this as a center of gravity.	1 2 3 4 5 N/A

24 Div and 44 IMB (on southern Okinawa) is a candidate because it is a subordinate or local force grouping within 32 Army capable of the action conduct defensive operations in theater (Okinawa).

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to conduct defensive operations would not enable US to seize Okinawa, since 62 Div (on central Shimajiri isthmus) would remain with adequate force to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

52. This is NOT a valid center of gravity for this scenario.	1 2 3 4 5
53. The rationale presented for rejecting this center of gravity is valid.	1 2 3 4 5
54. I have a different reason for rejecting this as a center of gravity.	1 2 3 4 5 N/A

I considered capabilities (besides military force) available to Japan to accomplish the action oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity:

Result: I found no capabilities to be a source of strength capable of sufficiently performing the action oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

55. I agree that no center of gravity candidates of this type should be considered in this situation.	1 2 3 4 5

I considered sources of strength that provide Japan the freedom of action to accomplish the action oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Result: I found no sources of strength that sufficiently provide freedom of action to oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

56. I agree that no center of gravity candidates of this type should be considered in this situation.	1 2 3 4 5

I considered sources of strength that provide the Japan the will to fight to accomplish the action oppose US operations to conduct amphibious forcible entry to establish a foothold on Okinawa in the assault phase.

Result: I found no sources of strength that sufficiently provide will to fight to oppose US operations to seize Okinawa in the ground operations phase to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

57. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

IV. Overall Center of Gravity Analysis

Review the following summary of candidates considered, eliminated, and selected based on the analysis presented in the previous section.

US	Japan
Assault Phase: TF51 (Joint Expeditionary Force) – eliminated **Main Landing Forces** – selected TF53 (Northern Attack Force) – eliminated TF55 (Southern Attack Force) – eliminated	<u>Opposing US Assault Phase:</u> Japanese Forces Okinawa – eliminated **Japanese Air Forces** – selected (including Kamikaze) The capability to **concentrate two divisions** at the site of the main US landing – selected
Ground Phase: **TF56 (Expeditionary Troops)** – selected III Amphibious Corps – eliminated XXIV Corps – eliminated	<u>Opposing US Ground Phase:</u> **32 Army** – selected 62 Div – eliminated 24 Div and 44 IMB – eliminated

Please respond to the following questions regarding the overall analysis:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

58. Overall the right center of gravity candidates were considered. 1 2 3 4 5

59. Overall the right center of gravity selections were chosen. 1 2 3 4 5

60. Overall, centers of gravity were chosen for valid reasons. 1 2 3 4 5

61. Overall, centers of gravity were eliminated for valid reasons. 1 2 3 4 5

62. Overall, the rationale for choosing centers of gravity was valid 1 2 3 4 5

V. Comments

Feel free to comment on any question (please indicate the question number) or add any other comments.

US campaign in Panama, 1989 (Operation Just Cause)

Name ____________________________ **Date** _______________

Office ____________________________

Phone ____________________________

Purpose

You have been selected to evaluate center of gravity analysis for an historical scenario based on your expertise in operational art. Your evaluation will support analysis of the results obtained in research regarding the determination of operational centers of gravity in support of an MMAS thesis. The results of your evaluation will be combined with those of other evaluators to form a baseline of expert opinion regarding evaluation.

Thank you for your support of this work.

Instructions

Please evaluate the analysis that follows according to:

- The identification of candidates considered as centers of gravity (note that a "candidate" in this analysis is something considered as a center of gravity, which is either accepted or rejected based on further analysis).
- The selection of "valid" centers of gravity from among those candidates and their rationale.
- The elimination of inappropriate centers of gravity from among candidates.
- The appropriateness of the rationale used throughout for identifying candidates and accepting/rejecting them as centers of gravity

First respond to the background questions, and then read the following sections, responding to questions as they occur in each section:

VI. Questions about your background
VII. Scenario Background
VIII. Individual Center of Gravity Candidates and Selections
IX. Overall Center of Gravity Analysis
X. Comments

Please note that you may comment on any response (please put them in *Section V*) but such comments are strictly optional.

I. Questions about your background

1. What is your military background?

Service ________________ Years of service ____

☐ Active ☐ Retired since _____________

Rank __________

2. Do you have any experience teaching the center of gravity concept?

☐ No experience teaching center of gravity

☐ Taught center of gravity at:

SSC level	______ Years	Comments _________________________
CGSC level	______ Years	Comments _________________________
Other	______ Years	Comments _________________________

Please respond to the following questions regarding your familiarity with center of gravity:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

3. I am familiar with the concept of center of gravity.	1 2 3 4 5
4. I consider myself qualified to determine operational centers of gravity.	1 2 3 4 5

II. Scenario Background

This center of gravity analysis is for the US campaign in Panama, 1989 (Operation Just Cause).

(Review the attached synopsis of Operation Just Cause as necessary)

Please respond to the following questions regarding the scenario:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

5. I am familiar with this campaign.	1 2 3 4 5
6. I consider myself qualified to determine operational centers of gravity regarding this campaign.	1 2 3 4 5
7. I have already formed opinions about operational center(s) of gravity for this campaign.	1 2 3 4 5

III. Individual Center of Gravity Candidates and Selections

Please read the following analysis and respond to questions as they occur:

I considered both friendly and enemy centers of gravity for the scenario. I considered these from the perspective of the US forces in that scenario. That is, the analysis is done according to the operational aims of the US in the scenario. A "friendly" center of gravity is a US center of gravity to be protected by the US, and an "enemy" center of gravity is a Panama center of gravity to be defeated by the US.

I considered centers of gravity related to the operation as a whole and did not distinguish phases for the purpose of analyzing centers of gravity for the US operation in Panama.

I considered <u>Disarm and dismantle the PDF</u> to be the operational aim of the US for this phase. I considered <u>Conduct offensive operations in theater (Panama) to</u> be an action that the US could take to accomplish that aim.

Friendly centers of gravity (operational level)

I considered the <u>forces</u> available to the US to accomplish the action <u>Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF</u>.

Result: I consider the following forces to be sufficiently capable of performing the action Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF to be considered as candidate centers of gravity:

<u>JTF South</u> is a candidate because it is the overall military force to be used by US during the operation and is capable of the action conduct offensive operations.

This candidate is NOT viable as a center of gravity choice in this situation. Although the defeat of its capability to Conduct offensive operations in theater (Panama) would prevent US from disarming and dismantling the PDF, a subordinate grouping of forces within this force, Assault Forces, was found to be a more focused center of gravity capable of this action.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

8. I agree that this is NOT a valid center of gravity for this scenario.	1	2	3	4	5	
9. The rationale presented for rejecting this center of gravity is valid.	1	2	3	4	5	
10. I have a different reason for rejecting this as a center of gravity.	1	2	3	4	5	N/A

<u>Assault Forces</u> (invading by airborne assault) is a candidate because it is a subordinate or local force grouping within JTF South capable of the action Conduct offensive operations in theater (Panama) during the operation to achieve the aim Disarm and dismantle the PDF

This candidate is a viable center of gravity choice because the defeat of its capability to Conduct offensive operations in theater (Panama) could prevent US from disarming and dismantling the PDF since the remaining US forces in country cannot conduct offensive operations with sufficient speed and surprise to accomplish the aim, and no further subordinate grouping of forces within

Assault Forces was found to be a more focused center of gravity since the PDF objectives are too dispersed for any subordinate force to accomplish the overall purpose.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

11. I agree that this is a valid center of gravity for this scenario.	1	2	3	4	5	
12. The rationale presented for choosing this center of gravity is valid.	1	2	3	4	5	
13. I have a different reason for choosing this as a center of gravity.	1	2	3	4	5	N/A

<u>In Country Forces</u> (forces already in Panama at the outset of Operation Just Cause) is a candidate because it is a subordinate or local force grouping within JTF South capable of the action Conduct offensive operations in theater (Panama) during the operation to achieve the aim Disarm and dismantle the PDF

This candidate is NOT viable as a center of gravity choice in this situation because the defeat of its capability to Conduct offensive operations in theater (Panama) would not prevent US from disarming and dismantling the PDF, since Assault_Forces still have adequate combat force to conduct offensive operations with sufficient speed and surprise to accomplish the aim disarm and dismantle the PDF to accomplish the aim.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

14. I agree that this is NOT a valid center of gravity for this scenario.	1	2	3	4	5	
15. The rationale presented for rejecting this center of gravity is valid.	1	2	3	4	5	
16. I have a different reason for rejecting this as a center of gravity.	1	2	3	4	5	N/A

I considered <u>capabilities</u> (besides military force) available to the US to accomplish the action <u>Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF</u>.

Result: I found no capabilities to be a source of strength capable of sufficiently performing the action <u>Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF</u> to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

17. I agree that no center of gravity candidates of this type should be considered in this situation.	1	2	3	4	5

I considered sources of strength that provide the US the <u>freedom of action</u> to accomplish the action <u>Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF</u>.

Result: I found no sources of strength that sufficiently provide freedom of action to Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

18. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide the US the will to fight to accomplish the action Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF.

Result: I found no sources of strength that sufficiently provide will to fight to Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

19. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

Enemy centers of gravity (operational level)

I considered opposing US offensive operations in theater (Panama) to be the operational aim of Panama for this phase. I considered Conduct defensive operations in theater (Panama) to be the action that Panama could take to accomplish that aim.

I considered the forces available to Panama to accomplish the action Conduct defensive operations in theater (Panama) to oppose US offensive operations in theater (Panama).

Result: I consider the following forces to be sufficiently capable of performing the action oppose US operations to Conduct offensive operations in theater (Panama) to Disarm and dismantle the PDF to be considered as candidate centers of gravity:

Panamanian Defense Forces (PDF) is a candidate because it is the overall military force to be used by Panama during the operation and is capable of the action Conduct defensive operations in theater (Panama).

This candidate is a viable center of gravity choice because the defeat of its capability to conduct defensive operations could enable US to disarm and dismantle the since it is the overall source of forces for this purpose and there would not be any remaining forces with this capability to accomplish the aim, and no further subordinate grouping of forces within the PDF was found to be a more focused center of gravity for this purpose since all of the subordinate units are too small and dispersed to effectively oppose the US operation.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

20. I agree that this is a valid center of gravity for this scenario. 1 2 3 4 5

21. The rationale presented for choosing this center of gravity is valid. 1 2 3 4 5

22. I have a different reason for choosing this as a center of gravity. 1 2 3 4 5 N/A

I considered capabilities (besides military force) available to Panama to accomplish the action conduct defensive operations to oppose US offensive operations in theater (Panama).

Result: I found no capabilities to be a source of strength capable of sufficiently performing the action conduct defensive operations to oppose US offensive operations in theater (Panama) to be considered as candidate centers of gravity.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

23. I agree that no center of gravity candidates of this type should be considered in this situation. 1 2 3 4 5

I considered sources of strength that provide Panama the freedom of action to accomplish the action conduct defensive operations to oppose US offensive operations in theater (Panama).

Result: I found the following source of strength that sufficiently provides freedom of action to oppose US offensive operations in theater (Panama) to be considered a candidate center of gravity.

Commandancia Forces (elements of the PDF stationed to protect the Commandancia) is a candidate because it provides freedom of action by protecting the PDF headquarters allowing the centralized command and control of the PDF.

This candidate is a viable center of gravity choice because the defeat of Commandancia Forces capability to protect the PDF headquarters leads to the elimination of the centralized command and control of the PDF, directly enabling the US to disarm and dismantle the PDF since the loss of centralized control would limit PDF freedom of action by eliminating Noriega's control and cause the PDF units to become isolated and ineffective against US operations.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

24. I agree that this is a valid center of gravity for this scenario. 1 2 3 4 5

25. The rationale presented for choosing this center of gravity is valid. 1 2 3 4 5

26. I have a different reason for choosing this as a center of gravity. 1 2 3 4 5 N/A

I considered sources of strength that provide Panama the will to fight to accomplish the action conduct defensive operations to oppose US offensive operations in theater (Panama).

Result: I found the following source of strength that sufficiently provides will to fight to oppose US offensive operations in theater (Panama) to be considered a candidate center of gravity.

6th and 7th Rifle Companies (co-located at Rio Hato) is a candidate because it provides will to fight by providing a particularly loyal unit that maintains Noriega's control over the PDF.

This candidate is a viable center of gravity choice because the defeat of 6th and 7th Rifle Companies capability to maintain Noriega's control over the PDF leads to the loss of the most loyal and capable elements of the PDF, would expose Noriega to capture, and cause the remainder of the PDF to become demoralized, directly enabling the US to disarm and dismantle the PDF since this leads to the loss of the PDF's will to fight against US operations.

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

27. I agree that this is a valid center of gravity for this scenario.	1	2	3	4	5	
28. The rationale presented for choosing this center of gravity is valid.	1	2	3	4	5	
29. I have a different reason for choosing this as a center of gravity.	1	2	3	4	5	N/A

IV. Overall Center of Gravity Analysis

Review the following summary of candidates considered, eliminated, and selected based on the analysis presented in the previous section.

US	Panama
JTF South – eliminated **Assault Forces** – viable In Country Forces – eliminated	**PDF** – viable **Commandancia Forces** – viable **6th and 7th Rifle Companies** – viable

Please respond to the following questions regarding the overall analysis:

Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree 5=Strongly Agree

30. Overall the right center of gravity candidates were considered. 1 2 3 4 5

31. Overall the right center of gravity selections were chosen. 1 2 3 4 5

32. Overall, centers of gravity were chosen for valid reasons. 1 2 3 4 5

33. Overall, centers of gravity were eliminated for valid reasons. 1 2 3 4 5

34. Overall, the rationale for choosing centers of gravity was valid 1 2 3 4 5

V. Comments

Feel free to comment on any question (please indicate the question number) or add any other comments.

APPENDIX E

EVALUATION DATA

This appendix contains the data collected using the evaluation instruments in appendix D. The use of expert evaluation in the research methodology is explained in chapter 3, in the section, “Evaluation of Results.” The analysis of this data is presented in chapter 4, in the section “Results of Expert Evaluation.” The tables and figures that follow present the following data:

1. Raw data from evaluations of the Okinawa scenario (tables 3 and 4)
2. Raw data from evaluations of the Panama scenario (table 5)
3. Aggregated responses for section IV questions about overall acceptability, both evaluations (table 6 and figure 6)
4. Aggregated responses for selected section III questions about individual determinations, both evaluations (table 7 and figure 7).

Table 3. Raw Data from Evaluations of the Okinawa Scenario (1-34)

Question	Mean	Median	Mode	Respondents 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	27.9	28	29	28	20	26	27	26	33	33	27	29	26	29	30	25	29	29
2	5.2	4	4	8	4	6	4	3	14	2	1	4	1	4	14	3	12	1
3	4.7	5	5	5	5	5	5	5	4	5	5	4	4	5	4	5	5	4
4	4.4	4	4	5	5	5	5	5	4	4	4	4	4	4	4	5	5	4
5	4.6	5	5	5	5	5	5	5	4	4	5	4	4	4	4	5	5	4
6	4.6	5	5	5	5	5	5	5	4	4	5	4	4	4	4	5	5	4
7	4.2	4	4	4	5	4	4	5	4	3	4	4	4	4	4	5	5	4
8	3.6	4	4	4	2	4	4	5	2	2	5	5	4	4	2	2	4	4
9	3.6	4	4	5	2	4	4	5	2	2	5	5	4	4	2	2	4	4
10	0.8	0	0	0	5	0	0	0	3	3	0	0	2	0	0	0	0	0
11	4.0	4	4	5	2	4	5	4	2	3	5	4	5	4	4	4	5	4
12	4.0	4	4	5	2	4	5	4	2	3	5	4	5	4	4	4	4	5
13	0.6	0	0	0	0	0	2	0	3	3	0	0	2	0	0	0	0	0
14	4.1	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	5	4
15	3.8	4	4	4	5	4	4	4	2	2	4	4	4	4	4	4	3	4
16	0.6	0	0	0	0	0	2	0	3	4	0	0	2	0	0	0	0	0
17	4.1	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
18	3.7	4	4	4	4	4	4	4	2	2	4	4	4	4	4	4	3	4
19	0.7	0	0	0	0	0	2	0	3	4	0	0	2	0	0	0	0	
20	3.6	4	4	3	2	2	4	5	4	4	5	4	4	2	4	1	5	4
21	3.8	4	4	4	2	2	4	4	4	5	5	2	4	2	4	5	5	4
22	4.2	4	4	5	4	4	4	4	4	5	5	2	5	4	4	5	5	4
23	3.5	4	4	4	4	3	4	4	2	2	4	4	1	3	4	5	5	2
24	2.9	3	4	4	4	3	2	4	2	1	4	4	1	3	2	2	5	2
25	1.1	0	0	0	0	0	4	0	3	1	0	0	0	0	4	5		
26	3.4	4	4	5	4	4	4	4	2	2	4	4	1	4	4	1	5	2
27	3.4	4	4	5	4	4	4	4	2	3	4	4	1	4	4	1	4	2
28	0.6	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	4	
29	3.1	3	4	3	3	4	4	2	2	3	4	3	4	4	4	1	1	4
30	2.8	3	4	3	3	4	2	2	2	2	4	3	4	4	2	1	1	4
31	1.1	0	0	0	0	0	4		3	3	0		2	0	4	0	0	
32	3.9	4	4	4	5	3	4	2	4	3	5	4	3	4	4	5	5	4
33	3.8	4	5		2	5	4	2	4	1	5	2	5	4	4	5	5	4
34	4.2	4	4	5	5	4	4	5	4	4	4	3	4	4	4	5	5	4

Table 4. Raw Data from Evaluations of the Okinawa Scenario (35-62)

Question	Mean	Median	Mode	Respondents 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
35	4.18	4	4	5	5	4	4	5	4	4	4	3	4	4	4	4	5	4
36	0.4	0	0	0	0	2	0	0	3	0	0	0	2	0	0	0	0	
37	3.7	4	4	3	4	4	2	5	4	2	4	3	4	2	4	5	5	4
38	3.5	4	4	3	4	4	2	5	2	3	4	3	4	2	4	5	3	4
39	0.7	0	0	0	0	2	0	0	3	0	0	0	2	0	0	0	4	
40	3.6	4	4	3	4	4	2	5	2	3	4	3	4	2	4	5	5	4
41	3.6	4	4	3	4	4	2	5	2	3	4	3	4	2	4	5	4	4
42	0.9	0	0	0	0	2	0	0	3	3	0	0	2	0	0	0	4	
43	4.0	4	4		4	4	3	4	4	3	5	4	4	3	4	5	5	4
44	3.7	4	4	3	4	4	3	2	4	3	5	2	4	3	4	5	5	4
45	4.1	4	4		4	5	3	4	4	4	5	2	5	3	4	5	5	
46	4.4	4	4	5	5	4	5	5	4	4	4	4	5	4	4	5	5	4
47	4.6	5	5	5	5	4	5	5	4	4	5	4	5	4	4	5	5	4
48	0.4	0	0	0	0	0	2	0	3	0	0	0	2	0	0	0	0	
49	4.1	4	4	5	4	4	4	4	2	3	5	4	4	4	4	5	5	4
50	4.1	4	4	5	4	4	4	4	2	3	5	4	4	4	4	5	5	4
51	0.4	0	0	0	0	0	2	0	3	0	0	0	2	0	0	0	0	
52	3.9	4	4	5	4	4	4	4	4	3	1	4	4	4	4	5	5	4
53	3.8	4	4	5	4	4	4	4	2	3	1	4	4	4	4	5	5	4
54	0.4	0	0	0	0	0	2	0	3	0	0	0	2	0	0	0	0	
55	3.9	4	4		4	4	4	2	4	4	5	4	4	4	4	2	5	4
56	3.9	4	4	5	5	2	4	2	4	4	5	2	4	4	4	5	5	4
57	3.9	4	5		3	2	5	4	4	2	5	2	5	3	4	5	5	4
58	3.9	4	4	4	3	4	4	4	4	3	5	4	4	4	4	4	4	4
59	3.5	4	4	4	3	4	4	4	2	3	4	4	4	4	2	2	4	4
60	3.9	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4
61	3.9	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4
62	3.9	4	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4

Table 5. Raw Data from Evaluations of the Panama Scenario

Question	Mean	Median	Mode	Respondents 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	27.9	28	29	28	20	26	27	26	33	33	27	29	26	29	30	25	29	29
2	5.2	4	4	8	4	6	4	3	14	2	1	4	1	4	14	3	12	1
3	4.6	5	5	5	5	5	5	5	4	4	5	4	4	5	4	5	5	4
4	4.4	4	4	5	5	5	5	5	4	4	4	4	4	4	4	5	5	4
5	4.6	5	5	5	5	5	5	5	4	4	4	4	5	4	4	5	5	4
6	4.4	4	4	5	5	5	5	5	4	4	4	4	4	4	4	5	5	4
7	4.1	4	4	5	5	4	4	5	4	4	3	3	4	3	4	5	5	3
8	4.1	4	4	5	4	4	4	5	4	4	5	4	4	4	4	5	1	4
9	3.9	4	4	5	4	4	4	5	4	2	5	4	4	4	4	5	1	4
10	0.3	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	
11	3.9	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	1	4
12	3.9	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	1	4
13	0.5	0	0	0	0	0	2	0	0	3	0	0	2	0	0		0	
14	3.8	4	4	4	4	4	4	2	4	2	5	4	4	4	4	2	5	4
15	3.6	4	4	4	4	4	4	2	4	2	5	4	4	4	4	2	2	4
16	0.7	0	0	0	0	0	0	0	3	0	0	0	2	0	0		5	
17	3.7	4	4	2	4	2	4	4	4	4	5	2	4	2	4	5	5	4
18	3.6	4	4	3	4	2	4	4	4	2	5	2	4	2	4	5	5	4
19	3.5	4	4	3	4	2	4	4	4	4	5	2	4	2	4	2	5	3
20	4.3	4	4	4	2	5	4	5	4	4	5	5	5	4	4	5	5	4
21	4.2	4	4	4	2	4	4	5	4	4	5	5	4	4	4	5	5	4
22	0.3	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	
23	3.8	4	4	4	2	4	4	4	4	2	5	2	4	4	4	4	5	4
24	3.5	4	4	4	4	4	4	1	2	4	3	3	4	4	4	4	2	4
25	3.5	4	4	4	4	4	4	1	2	4	3	3	4	4	4	4	2	4
26	0.3	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	
27	2.5	2	2	4	2	3	2	2	2	4	4	3	2	4	2	1	1	2
28	2.6	2	2	4	2	3	2	2	2	4	4	3	2	4	2	1	1	4
29	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
30	3.6	4	4	4	3	4	4	4	4	2	5	4	4	4	4	2	2	4
31	3.5	4	4	4	3	4	4	3	2	3	4	4	4	4	4	4	1	4
32	3.6	4	4	4	4	4	4	3	2	3	4	4	4	4	4	4	1	4
33	3.5	4	4	4	4	4	4	3	2	2	4	4	4	4	4	2	2	4
34	3.5	4	4	4	3	4	4	3	3	3	4	4	4	4	4	2	2	4

Table 6. Aggregated Responses for Section IV Questions about Overall Acceptability, Both Evaluations

Questions of type	***Mean***	***Median***	***Mode***	***SD***	***D***	***N***	***A***	***SA***
				Do not agree			***Agree***	
Overall, the right center of gravity candidates were considered	3.8	4	4	0	3	3	22	2
				0%	10%	10%	73%	7%
				20%			80%	
Overall, the right center of gravity selections were chosen	3.5	4	4	1	4	5	20	0
				3%	13%	17%	67%	0%
				33%			67%	
Overall, centers of gravity were chosen for valid reasons	3.7	4	4	1	2	2	25	0
				3%	7%	7%	83%	0%
				17%			83%	
Overall, centers of gravity were eliminated for valid reasons	3.6	4	4	0	5	1	24	0
				0%	17%	3%	80%	0%
				20%			80%	

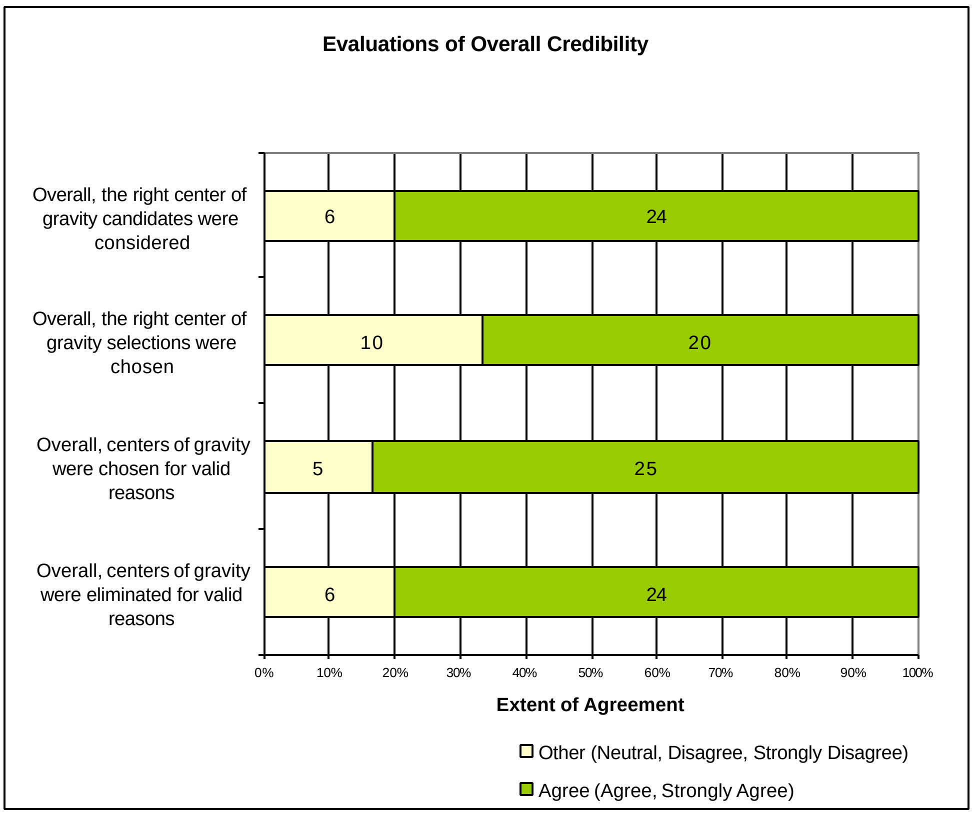


Figure 6. Evaluations of Overall Credibility

Table 7. Aggregated Responses for Section III Questions about Individual Acceptability, Both Evaluations

Questions of type	*Mean*	*Median*	*Mode*	*SD*	*D*	*N*	*A*	*SA*
					Do not agree		*Agree*	
Selection of a COG (all sources)	3.7	4	4	8	17	10	73	27
				6%	13%	7%	54%	20%
					26%		74%	
Selection of a COG from among forces	4.0	4	4	3	6	2	52	27
				3%	7%	2%	58%	30%
					12%		88%	
Selection of a COG from capabilities or other sources of strength	3.0	3	4	5	11	8	21	0
				11%	24%	18%	47%	0%
					53%		47%	
Rationale for choosing a candidate as a COG	3.7	4	4	8	18	10	75	24
				6%	13%	7%	56%	18%
					27%		73%	
Elimination of a candidate as a COG	3.8	4	4	3	18	9	93	27
				2%	12%	6%	62%	18%
					20%		80%	
Rationale for eliminating a candidate as a COG	3.6	4	4	4	27	13	84	22
				3%	18%	9%	56%	15%
					29%		71%	
No candidate should be considered for the situation	3.8	4	4	2	38	18	106	55
				1%	17%	8%	48%	25%
					26%		74%	

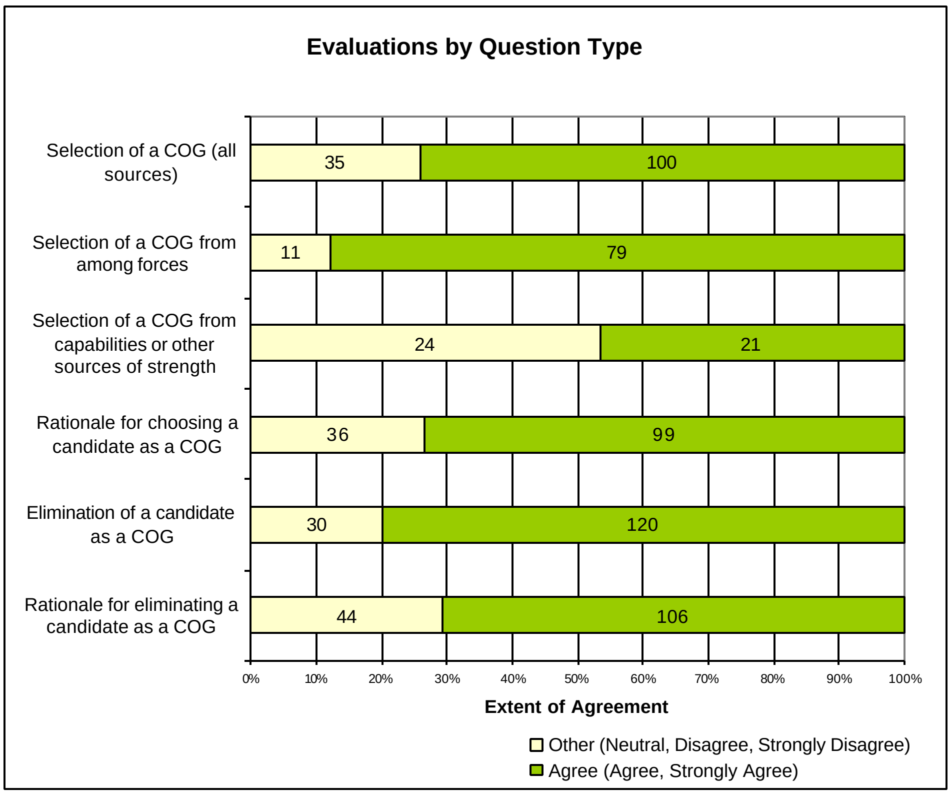


Figure 7. Evaluations by Question Type

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